QCD and Monte Carlo event generators (Lecture 2 — Hands-on session)

Marius Wiesemann

Max-Planck-Institut für Physik



BND summer school 2024 Blankenberge (Belgium), September 2-12th, 2024







MATRIX features

 \bigcirc processes, q_T subtraction + cutoff extrapolation, extensions, ...

\odot How to compile the code + How to run the code \rightarrow hands on!

basic information & some hidden features B

Folder structure

Implement/access/understand certain features: -> hands on!

- B
- adding a distribution & comparison to ATLAS data
- "normal" processes vs. photon processes



changing the inputs (change precision, change QCD/EW order, change machine energy...)





OpenLoops (COLLIER, CUTTOOLS, ...)

THI

MATRIX **MUNICH Automates qT Subtraction** and Resummation to Integrate X-sections.

Amplitudes

Dedicated 2-loop codes $(\overline{\mathbf{V}}\overline{\mathbf{V}}\overline{\mathbf{M}}\mathbf{P}, \overline{\mathbf{G}}\overline{\mathbf{I}}\overline{\mathbf{N}}\overline{\mathbf{A}}\overline{\mathbf{C}}, \overline{\mathbf{T}}\overline{\mathbf{D}}\overline{\mathbf{H}}\overline{\mathbf{P}}\overline{\mathbf{L}}, \dots)$

MUNICH MUlti-chaNnel Integrator at Swiss (CH) precision

 q_{T} subtraction $\Leftrightarrow q_{\mathrm{T}}$ resummation

The MATRIX team



Massimiliano "Morpheus" Grazzini Stefan "Neo" Kallweit Marius "Trinity" Wiesemann

The MATRIX team



Luca "Cypher" Rottocore/ Buonottoli

Massimiliano "Morpheus" Grazzini

Stefan "Neo" Kallweit

Marius "Trinity" Wiesemann

Javier "Trinity" Mazzitelli Simone "Trinity" Devoto

Chiara "Trinity" Savoini



process	status	comment
pp→Ζ/γ*(→ℓℓ/νν)	1	validated analytically + FEWZ
$pp \rightarrow W(\rightarrow \ell \nu)$	\checkmark	validated with FEWZ, NNLOjet
pp→H	\checkmark	validated analytically (by SusHi)
рр→үү	\checkmark	validated with 2yNNLO
pp→Z γ→ℓℓγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
pp→Z γ→ v vγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
pp→₩γ→ℓvγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
рр→үүү	\checkmark	[Kallweit, Sotnikov, MW '20]
pp→ZZ	\checkmark	[Cascioli et al. '14]
pp→ZZ→ℓℓℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]
pp→ ZZ →ℓℓℓ'ℓ'	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]
pp→ZZ→ℓℓν'v'	\checkmark	[Kallweit, MW '18]
pp→ZZ/WW→ℓℓvv	\checkmark	[Kallweit, MW '18]
pp→WW	\checkmark	[Gehrmann et al. '14]
pp→ WW →ℓv ℓ'v'	1	[Grazzini, Kallweit, Pozzorini, Rathlev, MW '16]
pp→WZ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '16]
pp→WZ→ℓvℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '17]
pp→WZ→ℓ'v'ℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '17]
pp→tt	✓	[Catani, Devoto, Grazzini, Kallweit, Mazzitelli, Sargsyan, '19]



not yet in public release

process	status	comment
 рр→НН	(🗸)	[Grazzini, Kallweit, Rathlev '15]
рр→ bb	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit
pp→ ttH	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit Savioni, '19]
pp→ bbW	(🗸)	[Buonocore, Devoto, Kallweit, Mazzitelli, F Savoini, '23]
pp→tt₩	(🗸)	[Buonocore, Devoto, Grazzini, Kallweit, M Rottoli, Savoini, '23]



process	status	comment
pp→Ζ/γ*(→ℓℓ/νν)	\checkmark	validated analytically + FEWZ
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рр→Н	\checkmark	validated analytically (by SusHi)
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pp→Z γ <i>→</i> ℓℓγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
ρ ρ→ Ζ γ→ννγ	1	[Grazzini, Kallweit, Rathlev '15]
pp→₩γ→ℓv γ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
рр→үүү	\checkmark	[Kallweit, Sotnikov, MW '20]
pp→ZZ	\checkmark	[Cascioli et al. '14]
pp→ZZ→ℓℓℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]
pp→ ZZ →ℓℓℓ'ℓ'	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]
pp→ZZ→ℓℓν"v"	\checkmark	[Kallweit, MW '18]
pp→ZZ/WW→ℓℓvv	\checkmark	[Kallweit, MW '18]
pp→WW	\checkmark	[Gehrmann et al.'14]
pp→ WW →ℓv ℓ'v'	\checkmark	[Grazzini, Kallweit, Pozzorini, Rathlev, MW '16]
pp→WZ	1	[Grazzini, Kallweit, Rathlev, MW '16]
pp→WZ→ℓvℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '17]
pp→WZ→ℓ'v'ℓℓ	1	[Grazzini, Kallweit, Rathlev, MW '17]
pp→tt	✓	[Catani, Devoto, Grazzini, Kallweit, Mazzitelli, Sargsyan, '19]





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рр→ bb	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit
pp→ttH	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit Savioni, '19]
рр→ bbW	(🗸)	[Buonocore, Devoto, Kallweit, Mazzitelli, F Savoini, '23]
pp→ttW	([Buonocore, Devoto, Grazzini, Kallweit, M Rottoli, Savoini, '23]





process	status	comment
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рр→Н	\checkmark	validated analytically (by SusHi)
рр→үү	\checkmark	validated with 2γNNLO
pp→Z γ <i>→</i> ℓℓγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
ρ ρ→ Ζ γ→ννγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
pp→₩γ→ℓvγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
рр→үүү	\checkmark	[Kallweit, Sotnikov, MW '20]
pp→ZZ	\checkmark	[Cascioli et al. '14]
pp→ZZ→ℓℓℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]
pp→ ZZ →ℓℓℓ'ℓ'	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]
pp→ZZ→ℓℓν'v'	\checkmark	[Kallweit, MW '18]
pp→ ZZ/WW →ℓℓvv	\checkmark	[Kallweit, MW '18]
pp→WW	\checkmark	[Gehrmann et al. 'I4]
pp→ WW →ℓv ℓ'v'	\checkmark	[Grazzini, Kallweit, Pozzorini, Rathlev, MW '16]
pp→WZ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '16]
pp→WZ→ℓvℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '17]
pp→WZ→ℓ'v'ℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '17]
pp→ tt	\checkmark	[Catani, Devoto, Grazzini, Kallweit, Mazzitelli, Sargsyan, '19]



single boson processes

photon processes

not yet in public release

process	status	comment			
рр→НН	(🗸)	[Grazzini, Kallweit, Rathlev '15]			
pp→ bb	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit			
pp→ttH	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit Savioni, '19]			
pp→ bbW	(🗸)	[Buonocore, Devoto, Kallweit, Mazzitelli, F Savoini, '23]			
pp→tt₩	(🗸)	[Buonocore, Devoto, Grazzini, Kallweit, M Rottoli, Savoini, '23]			



process	status	comment
ρρ→Ζ/γ*(→ℓℓ/νν)	\checkmark	validated analytically + FEWZ
$pp \rightarrow W(\rightarrow \ell \nu)$	\checkmark	validated with FEWZ, NNLOjet
рр→Н	\checkmark	validated analytically (by SusHi)
рр→үү	\checkmark	validated with 2γNNLO
pp→Z γ→ℓℓγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
pp→ Ζ γ→ννγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
pp→₩γ→ℓvγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]
рр→үүү	\checkmark	[Kallweit, Sotnikov, MW '20]
pp→ZZ	\checkmark	[Cascioli et al. '14]
pp→ZZ→ℓℓℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]
pp→ ZZ →ℓℓℓℓ'ℓ'	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]
pp→ZZ→ℓℓv'v'	\checkmark	[Kallweit, MW '18]
pp→ ZZ/WW →ℓℓvv	\checkmark	[Kallweit, MW '18]
pp→WW	\checkmark	[Gehrmann et al. 'I4]
pp→ WW →ℓv ℓ'v'	\checkmark	[Grazzini, Kallweit, Pozzorini, Rathlev, MW '16]
pp→WZ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '16]
pp→WZ→ℓvℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '17]
pp→WZ→ℓ'v'ℓℓ	1	[Grazzini, Kallweit, Rathlev, MW '17]
pp→tt	✓	[Catani, Devoto, Grazzini, Kallweit, Mazzitelli, Sargsyan, '19]



single boson processes

photon processes

massive diboson processes

not yet in public release

process	status	comment
рр→НН	(🗸)	[Grazzini, Kallweit, Rathlev '15]
pp→ bb	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit
pp→ttH	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzito Savioni, '19]
pp→ bbW	(🗸)	[Buonocore, Devoto, Kallweit, Mazzitelli, R Savoini, '23]
pp→ttW	([Buonocore, Devoto, Grazzini, Kallweit, M Rottoli, Savoini, '23]



process	status	comment				
ρρ→Ζ/γ*(→ℓℓ/νν)	\checkmark	validated analytically + FEWZ	cingle becon			
$pp \rightarrow W(\rightarrow \ell \nu)$	\checkmark	validated with FEWZ, NNLOjet	single boson			
рр→Н	\checkmark	validated analytically (by SusHi)	processes			
рр→үү	\checkmark	validated with 2yNNLO				
pp→Z γ→ℓℓγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]				
ρ ρ→ Ζ γ→ννγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]	photon			
pp→₩γ→ℓvγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]	processes			
рр→үүү	\checkmark	[Kallweit, Sotnikov, MW '20]				
pp→ZZ	~	[Cascioli et al. '14]	•	heavy-qu	ark	
pp→ZZ→ℓℓℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]	massive	processes not vet in public release		
pp→ ZZ →ℓℓℓ'ℓ'	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]	alboson			
pp→ZZ→ℓℓν'v'	\checkmark	[Kallweit, MW '18]	processes			
pp→ ZZ/WW →ℓℓvv	 Image: A second s	[Kallweit, MW '18]	process	status	comment	
pp→WW	\checkmark	[Gehrmann et al. '14]	рр→ НН	(🗸)	[Grazzini, Kallweit, Rathlev '15]	
pp→ WW →ℓv ℓ'v'	\checkmark	[Grazzini, Kallweit, Pozzorini, Rathlev, MW '16]	рр→bb	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit	
pp→WZ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '16]	pp→ttH	(🗸)	[Catani, Devoto, Grazzini, Kallweit, Mazzit	
pp→₩Z→ℓvℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '17]			[Buonocore, Devoto, Kallweit, Mazzitelli, F	
pp→₩Z→ℓ'v'ℓℓ		[Grazzini, Kallweit, Rathlev, MW '17]	рр⊸ддуу	(🗸)	- Šavoini, '23]	
pp→tt	\checkmark	[Catani, Devoto, Grazzini, Kallweit, Mazzitelli, Sargsyan, '19]	pp→ttW	(🗸)	[Buonocore, Devoto, Grazzini, Kallweit, M Rottoli, Savoini, '23]	





process	status	comment				
pp→ Ζ/γ *(→ℓℓ/vv)	\checkmark	validated analytically + FEWZ	cingle becon			
$pp \rightarrow W(\rightarrow \ell \nu)$	\checkmark	validated with FEWZ, NNLOjet	single boson			
рр→Н	\checkmark	validated analytically (by SusHi)	processes			
рр→үү	\checkmark	validated with 2yNNLO				
pp→Ζ γ→ℓℓγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]				
pp→ Ζ γ→ννγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]	pnoton			
pp→₩γ→ℓvγ	\checkmark	[Grazzini, Kallweit, Rathlev '15]	processes			
рр→үүү	\checkmark	[Kallweit, Sotnikov, MW '20]				heavy-quar
pp→ZZ	~	[Cascioli et al. '14]		heavy-qu	ark	colour single
pp→ZZ→ℓℓℓℓ	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]	massive	processes		processes
pp→ ZZ →ℓℓℓ'ℓ'	\checkmark	[Grazzini, Kallweit, Rathlev '15], [Kallweit, MW '18]	alboson	not vet i	n public	release
pp→ZZ→ℓℓν"v"	\checkmark	[Kallweit, MW '18]	processes			
pp→ ZZ/WW →ℓℓvv	 Image: A second s	[Kallweit, MW '18]	process	status		comment
pp→WW	\checkmark	[Gehrmann et al. '14]	рр→НН	(🗸)	[Grazzini, Kall	weit, Rathlev '15]
pp→ WW →ℓv ℓ'v'	\checkmark	[Grazzini, Kallweit, Pozzorini, Rathlev, MW '16]	pp→bb	(🗸)	[Catani, Devo	to, Grazzini, Kallweit, Mazzito
pp→WZ	\checkmark	[Grazzini, Kallweit, Rathlev, MW '16]	pp→ttH		[Catani, Devo	to, Grazzini, Kallweit, Mazzito
pp→WZ→ℓvℓℓ	1	[Grazzini, Kallweit, Rathlev, MW '17]			Savioni, '19]	
pp→₩Z→ℓ'v'ℓℓ	1	[Grazzini, Kallweit, Rathlev, MW '17]	рр→ ьь ₩	(🗸)	[Buonocore, L Savoini, '23]	Jevoto, Kallweit, Mazzitelli, P
pp→tt	√	[Catani, Devoto, Grazzini, Kallweit, Mazzitelli, Sargsyan, '19]	pp→ttW	(🗸)	[Buonocore, E Rottoli, Savoin	Devoto, Grazzini, Kallweit, M ni, '23]















NANR https://matrix.hepforge.org [Grazzini, Kallweit, MW '17]

Matrix v1 (fall 2017):

- → automated NNLO framework
- \rightarrow q_T subtraction
- \rightarrow colour-singlet $2 \rightarrow 1$ and $2 \rightarrow 2$
- → publicly available

Matrix v2 (summer 2021):

- → gg NLO QCD corrections
- → NLO EW corrections
- → various QCD-EW combination schemes → enhance statistics in high-energy tails

current Matrix extensions

MATRIX+RADISH

https://matrix.hepforge.org/matrix+radish.html [Kallweit, Re, Rottoli, MW '20]

 \rightarrow N³LL resummation for singlet p_T \rightarrow NNLL resummation for jet p_T \rightarrow NNLL for joint singlet p_T & jet p_T

MATRIX+PINEAPPL

[Devoto, Kallweit, Schwan 'to appear]

→ creation of PDF grids for PDF fits → automatic PDF & a_S variation



Matrix v2.1 (spring 2023):

- → included linear power corrections
- \rightarrow added pp $\rightarrow \gamma\gamma\gamma$ and pp \rightarrow tt
- \rightarrow bin-wise r_{cut} extrapolation
- → double-differential distributions





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MATRIX+RadISH framework

***** General interface between MATRIX and RadISH codes:

high-accuracy multi-differential resummation of various transverse observables matching to NNLO QCD integrated cross section

* **MATRIX** (v1.1) [Grazzini, Kallweit, MW '17] NNLO QCD, phase space, perturbative ingredients (amplitudes, coefficients, ...)

* **RadISH** [Monni, Re, and Torrielli '16], [Bizon, Monni, Re, Rottoli, Torrielli '18], [Monni, Rottoli, Torrielli '19] resummation formalism in direct space (not in b-space) numerical approach (like a semi-inclusive parton shower) single-differential resummation [Monni, Re, and Torrielli '16], [Bizon, Monni, Re, Rottoli, Torrielli '18] and double-differential resummation [Monni, Rottoli, Torrielli '19]

click here: https://matrix.hepforge.org/matrix+radish.html

[Kallweit, Re, Rottoli, MW '20]

all processes available in MATRIX (any color-singlet process possible where 2-loop known)



MATRIX+RadISH results



QCD and Monte Carlo event generators (Lecture 2 — hands-on session)

September 6, 2024





MATRIX alle Hawaii [Devoto, Kallweit, Schwan 'to appear]



./matrix --hawaii \$

Marius Wiesemann (MPP Munich)

QCD and Monte Carlo event generators (Lecture 2 – hands-on session)



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September 6, 2024

MATRIX alle Hawaii

[Devoto, Kallweit, Schwan 'to appear]

* General interface between MATRIX and PineAPPL codes:

all processes available in MATRIX (implemented in MATRIX main release, v2.1 at the moment)

creation of NNLO PDF grids that can applied in PDF fits and to do PDF/scale variations



Sample application from

Reduced mass and energy cross sections:

- NNLO QCD+NLO SM $(\mu_R = \mu_F = m_t + m_H/$
- PDF recommendation:

PDF4LHC21_40 for partons, LUXqed17_plus_PDF4L for photons

can be straightforwardl through **PINEAPPL** grid with scale, PDF and α_s

(theory uncertainties ca directly in MATRIX)

1 LHCHXSWG							
	$\sqrt{s} [\text{TeV}]$	$m_H \; [\text{GeV}]$	XS [fb]	\pm QCD Scale Unc.	\pm THU	$\pm \alpha_s$ Unc.	\pm PDF Unc.
y scan for <i>ttH</i>	13	124.6	532.0	$\pm 3.1\%$	$\pm 0.6\%$	$\pm 1.7\%$	$\pm 2.3\%$
	13	125	528.4	$\pm 3.2\%$	$\pm 0.7\%$	$\pm 1.7\%$	$\pm 2.3\%$
1	13	125.09	526.6	$\pm 3.1\%$	$\pm 0.7\%$	$\pm 1.7\%$	$\pm 2.3\%$
(2)	13	125.38	522.7	$\pm 3.1\%$	$\pm 0.7\%$	$\pm 1.7\%$	$\pm 2.3\%$
2)	13	125.6	519.9	$\pm 3.1\%$	$\pm 0.7\%$	$\pm 1.7\%$	$\pm 2.3\%$
	13	126	515.4	$\pm 3.1\%$	$\pm 0.7\%$	$\pm 1.7\%$	$\pm 2.3\%$
	13.6	124.6	596.6	$\pm3.0\%$	$\pm 0.7\%$	$\pm 1.6\%$	$\pm 2.2\%$
	13.6	125	589.9	$\pm2.9\%$	$\pm 0.7\%$	$\pm 1.6\%$	$\pm 2.2\%$
	13.6	125.09	589.6	$\pm3.0\%$	$\pm 0.7\%$	$\pm 1.6\%$	$\pm 2.2\%$
HC15_nnlo_100	13.6	125.38	586.2	$\pm3.0\%$	$\pm 0.7\%$	$\pm 1.6\%$	$\pm 2.2\%$
	13.6	125.6	583.5	$\pm3.0\%$	$\pm 0.7\%$	$\pm 1.6\%$	$\pm 2.2\%$
ly achieved	13.6	126	577.9	$\pm 3.1\%$	$\pm 0.7\%$	$\pm 1.6\%$	$\pm 2.2\%$
	14	124.6	639.7	$\pm2.9\%$	$\pm 0.7\%$	$\pm 1.6\%$	$\pm 2.2\%$
ds, together	14	125	636.1	$\pm3.0\%$	$\pm 0.6\%$	$\pm 1.6\%$	$\pm 2.2\%$
s_s uncertainties	14	125.09	633.3	$\pm2.9\%$	$\pm 0.6\%$	$\pm1.6\%$	$\pm 2.2\%$
alculated	14	125.38	632.4	$\pm 3.1\%$	$\pm 0.6\%$	$\pm1.6\%$	$\pm 2.2\%$
alculated	14	125.6	627.9	$\pm3.0\%$	$\pm 0.6\%$	$\pm1.6\%$	$\pm 2.2\%$
	14	126	621.2	$\pm 3.0\%$	$\pm 0.7\%$	$\pm 1.6\%$	$\pm 2.2\%$

...slide borrowed from Stefan Kallweit 22

How to compile MATRIX

After unpacking start MATRIX with:
\$\$./matrix

After unpacking start MATRIX with:
\$\$./matrix

Inside the MATRIX compilation shell
|===>> list



available processes. Try pressing TAB for auto-completion. Type "exit" or "quit" to stop.

|====>> list

- After unpacking start MATRIX with:
 \$\$./matrix
- Inside the MATRIX compilation shell
- |===>> list
- Iists all process IDs. Select ID, eg:
- |===>> ppeeexex04

[[wiesemann:~/different-branch-munich/MATRIX] ./matrix MATRIX: A fully-differential NNLO(+NNLL) process library $\overline{\Lambda}$ // ||_|| | |_| \\ // ||\\ || \\ // \\ // \\ Version: 1.0.0.release_candidate4 Aug 2017 Munich -- the MUlti-chaNnel Integrator at swiss (CH) precision --Automates qT-subtraction and Resummation to Integrate X-sections)==== +)==== +)==== + |)==== + |-)==== (grazzini@physik.uzh.ch) M. Grazzini S. Kallweit (stefan.kallweit@cern.ch) M. Wiesemann (marius.wiesemann@cern.ch) MATRIX is based on a number of different computations and tools from various people and groups. Please acknowledge their efforts by citing the list of references which is created with every run. <<MATRIX-MAKE>> This is the MATRIX process compilation. <<MATRIX-READ>> Type process_id to be compiled and created. Type "list" to show available processes. Try pressing TAB for auto-completion. Type "exit" or "quit" to stop. |========>> list process id description process >> on-shell Higgs production pph21 >> pp-->H ppz01 >> pp--> Z >> on-shell Z production on-shell W- production with CKM ppw01 >> pp--> W^->> ppwx01 on-shell W+ production with CKM >> pp--> W^+ >> ppeex02 p p --> e^- e^+ >> Z production with decay >> ppnenex02 pp-->ve^-ve^+ >> Z production with decay >> W- production with decay and CKM p p --> e^- v e^+ ppenex02 >> >> pp-->e^+ve^ppexne02 >> W+ production with decay and CKM >> p p --> gamma gamma gamma gamma production ppaa02 >> >> ppeexa03 p p --> e^- e^+ gamma Z gamma production with decay >> >> >> Z gamma production with decay p p --> v_e^- v_e^+ gamma ppnenexa03 >> p p --> e^- v_e^+ gamma ppenexa03 >> >> W- gamma production with decay p p --> e^+ v_e^- gamma >> W+ gamma production with decay ppexnea03 >> on-shell ZZ production ppzz02 >> pp--> Z Z >> ppwxw02 >> p p --> W^+ W^on-shell WW production >> >> p p --> e^- mu^- e^+ mu^+ >> ZZ production with decay ppemexmx04 >> ZZ production with decay ppeeexex04 >> p p --> e^- e^+ e^+ $ppeexnmnmx04 >> pp --> e^- e^+ v mu^- v mu^+$ >> ZZ production with decay $ppemxnmnex04 >> pp --> e^- mu^+ v mu^- v e^+$ >> WW production with decay ppeexnenex04 >> p p --> e^- e^+ v_e^- v_e^+ >> ZZ/WW production with decay $ppemexnmx04 >> pp --> e^- mu^- e^+ v mu^+$ >> W-Z production with decay ppeeexnex04 >> $p p --> e^{-} e^{+} v e^{+}$ >> W-Z production with decay $ppeexmxnm04 >> pp --> e^- e^+ mu^+ v mu^-$ >> W+Z production with decay ppeexexne04 >> $p p --> e^- e^+ e^+ v e^-$ >> W+Z production with decay |=======>> ppeeexex04

- After unpacking start MATRIX with:
 \$\$./matrix
- Inside the MATRIX compilation shell
 |===>> list
- Iists all process IDs. Select ID, eg:
- |===>> ppeeexex04
- for pp→ZZ→4ℓ. Confirming with
 |===>> y

	M. Wie	esemann	(ma	rius.wiesemann@cern.ch)			
	ATDIX is been an a number of different computations and tools						
	MATRIX is based on a number of different computations and tools						
	from various people and groups. Please acknowledge their efforts						
	by CI	ting the list of referen	ices which is o	created with every run. I			
١				/			
	ENN TH	is is the MATRIX process	compilation				
< <matrix-rea< td=""><td></td><td>ne process id to be com</td><td>iled and creat</td><td>ted Type "list" to show</td></matrix-rea<>		ne process id to be com	iled and creat	ted Type "list" to show			
	av:	ailable processes Try	pressing TAR f	or auto-completion Type			
	"ey	xit" or "quit" to stop.					
[]===========	==>> lis	st					
process_id		process	11	description			
ppn21	>>	p p> H	>>	on-shell Higgs production			
	>>		>>	on-shell 2 production			
	>>		>>	on-shell w- production with CKM			
	>>		>>	on-shell w+ production with CKM			
ppeexoz	~~		>>	Z production with decay			
ppnenex@2	~~	p p> v_e^- v_e^+	~~	2 production with decay			
ppenex@2	~~	p p> e ⁻ - v_e ⁻⁺	~~	w- production with decay and CKM			
ppexnee2	~~	p p> e ⁻⁺ v_e	~~	w+ production with decay and CKM			
ppaaez	~~	p p> gamma gamma	~~~	gamma gamma production			
ppeexa@3	~~	p p> e ⁻ - e ⁻ + gamma	>>	Z gamma production with decay			
ppnenexa@3	~~	p p> v_er- v_er+ gar	nma >>	Z gamma production with decay			
ppenexa03	~~	p p> e ⁻ - v_e ⁺ + gamma		w- gamma production with decay			
ppexneads	~~	p p> e + v_e - gamma		wr gamma production with decay			
	~~~	$p p \rightarrow z z$		on shall WW production			
	~~	$p p = -2 w + w^{2}$	1VT 22	77 production with docay			
	~~			77 production with decay			
			r mu∆± >>	77 production with decay			
	+ ~~		v_mu*+ >>	22 production with decay			
	+ ~~		· · · · · · · · · · · · · · · · · · ·	77/WW production with decay			
ppeexnenex04	* ~ ~	$p p = -> e^{-} mu^{-} e^{+} v$	/_C + //	$W_{\rm r}$ 7 production with decay			
	>>	$p p = -2 e^{-1} e^{-1$	_mu + >>	$W_{-2}$ production with decay			
ppeeexmex04	>>	p p> e^- e^+ mu^+ v		W+7 production with decay			
ppeeximitinii04	>>	$p p = - > e^{-} e^{+} e^{+} v$	_mu - >>	W+7 production with decay			
[]====================================	==>> nne	p p e - e - e - v_e		with decay			
< <matrix-mak< td=""><td>(F&gt;&gt; MA</td><td>TRIX usage agreements:</td><td></td><td></td></matrix-mak<>	(F>> MA	TRIX usage agreements:					
< <matrix-mak< td=""><td>(F&gt;&gt; MAT</td><td>TRIX is based on several</td><td>computations</td><td>studies and tools from</td></matrix-mak<>	(F>> MAT	TRIX is based on several	computations	studies and tools from			
	vai	rious people and groups	When using r	esults obtained by MATRIX			
	the	ese efforts must be ack	nowledged by c	iting the list of			
	re	ferences in the CITATIO	N.bib file. wh	ich is created in the			
	res	sult folder with every i	run.				
< <matrix-rea< td=""><td>D&gt;&gt; Do</td><td>you agree with these te</td><td>erms? Type "v"</td><td>to agree. or "n" to</td></matrix-rea<>	D>> Do	you agree with these te	erms? Type "v"	to agree. or "n" to			
	abo	ort the code.	, and the second s				
[ ] ============	==>> y						
< <matrix-mak< td=""><td>(E&gt;&gt; Th</td><td>is compilation of MATRIX</td><td>( uses directly</td><td>y the code OpenLoops from</td></matrix-mak<>	(E>> Th	is compilation of MATRIX	( uses directly	y the code OpenLoops from			
	hti	<pre>tp://openloops.hepforge</pre>	org. You have	to cite arXiv:1111.5206			
	fro	om F. Cascioli, P. Maier	hoefer, S. Po:	zzorini, when using			
	res	sults obtained with this	s installation				
< <matrix-rea< td=""><td>AD&gt;&gt; Do</td><td>you agree with these te</td><td>erms? Type "y"</td><td>to agree, or "n" to</td></matrix-rea<>	AD>> Do	you agree with these te	erms? Type "y"	to agree, or "n" to			
	abo	ort the code.					
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	ht	<pre>tp://vvamp.hepforge.org</pre>	You have to	cite arXiv:1503.04812			
	fro	om T. Gehrmann, A. von I	lanteuffel, L.	Tancredi, when using			
	res	sults obtained with this	s installation				
< <matrix-rea< td=""><td>AD&gt;&gt; Do</td><td>you agree with these te</td><td>erms? Type "y"</td><td>to agree, or "n" to</td></matrix-rea<>	AD>> Do	you agree with these te	erms? Type "y"	to agree, or "n" to			
	abo	ort the code.					
========	==>> y						

- After unpacking start MATRIX with:
  \$\$ ./matrix
- Inside the MATRIX compilation shell
  |===>> list
- Iists all process IDs. Select ID, eg:
- |===>> ppeeexex04
- for  $pp \rightarrow ZZ \rightarrow 4\ell$ . Confirming with

|==>> y

- the MATRIX usage agreements, the code will automatically start to:
  - dowload/compile of OpenLoops
  - compile of Cln and Ginac
  - compile MATRIX
  - download OpenLoops amplitudes
  - create MATRIX run folder for the process

ppemxnmnex04 >	<pre>&gt; p p&gt; e^- mu^+ v_mu^- v_e^+ &gt;&gt; WW production with decay</pre>
ppeexnenex04 >	> p p> e^- e^+ v_e^+ >> ZZ/WW production with decay
ppemexnmx04 >	> p p> e^- mu^- e^+ v_mu^+ >> W-Z production with decay
ppeeexnex04 >	> p p> e^- e^+ v_e^+ >> W-Z production with decay
ppeexmxnm04 >	> p p> e^- e^+ mu^+ v_mu^- >> w+2 production with decay
ppeexexnee4 >	> p p> e^+ e^+ v_e^- >> w+2 production with decay
A CHATDIV MAKENN	ppeeexex04
	MATRIX usage agreements: MATRIX is based on several computations, studies and tools from
SSHATKIA-HAKE//	various people and groups. When using results obtained by MATRIX
	these efforts must be acknowledged by citing the list of
	references in the CITATION hib file which is created in the
	result folder with every run
< <matrix-read>&gt;</matrix-read>	Do you agree with these terms? Type "y" to agree, or "n" to
	abort the code.
[]=====>>>	V
< <matrix-make>&gt;</matrix-make>	This compilation of MATRIX uses directly the code OpenLoops from
	http://openloops.hepforge.org. You have to cite arXiv:1111.5206
	from F. Cascioli, P. Maierhoefer, S. Pozzorini, when using
	results obtained with this installation.
< <matrix-read>&gt;</matrix-read>	Do you agree with these terms? Type "y" to agree, or "n" to
	abort the code.
[ <b> </b> ======>>>	У
< <matrix-make>&gt;</matrix-make>	This compilation of MATRIX uses directly the code VVamp from
	http://vvamp.hepforge.org. You have to cite arXiv:1503.04812
	from T. Gehrmann, A. von Manteuffel, L. Tancredi, when using
	results obtained with this installation.
< <mairix-keau>&gt;</mairix-keau>	bo you agree with these terms? Type "y" to agree, or "h" to
[]	abort the code.
CCMATRIX-MAKESS	y You have agreed with all MATRIX usage terms
< <matrix-make>&gt;</matrix-make>	Starting compilation
< <matrix-make>&gt;</matrix-make>	Using compiled LHAPDF installation under
	(config/MATRIX configuration)
	path_to_lhapdf=/mnt/shared/lhapdf_install/bin/lhapdf-config
< <matrix-make>&gt;</matrix-make>	OpenLoops already downloaded and compiled. Remove folder
	/home/wiesemann/different-branch-munich/MATRIX/src-external
	<pre>/OpenLoops-install if you want to re-download and re-compile</pre>
< <matrix-make>&gt;</matrix-make>	Cln already compiled. Remove folder /home/wiesemann/different-
	branch-munich/MATRIX/src-external/cln-install if you want to re-
A MATDIN MAKESS	Comple
< <mailtix-make>&gt;</mailtix-make>	Ginac already compiled. Remove Tolder /nome/wiesemann/different-
	re-compile
< <matrix_make>&gt;</matrix_make>	Compiling process <pre>coneeevev@4&gt; this may take a while</pre>
	(see make log file to monitor the progress)
< <matrix-make>&gt;</matrix-make>	OpenLoops pp]]]] amplitude already downloaded and compiled.
	Checking wether up-to-date
< <matrix-make>&gt;</matrix-make>	ppllll amplitude already installed and up-to-date.
< <matrix-make>&gt;</matrix-make>	OpenLoops ppllllj amplitude already downloaded and compiled.
	Checking wether up-to-date
< <matrix-make>&gt;</matrix-make>	ppllllj amplitude already installed and up-to-date.
< <matrix-make>&gt;</matrix-make>	OpenLoops ppllll2 amplitude already downloaded and compiled.
	Checking wether up-to-date
< <matrix-make>&gt;</matrix-make>	ppllll2 amplitude updated.
< <matrix-make>&gt;</matrix-make>	Creating process folder in "run"-directory: "/home/wiesemann
	/different-branch-munich/MATRIX/run/ppeeexex04_MATRIX"
< <mairix-info>&gt;</mairix-info>	Process folder successfully created.
< <maikix-inf0>&gt;</maikix-inf0>	cd (home (wiesemann (different breach munich (MATDI) (municipal)
COMATELY THEON	and start run by typing:
NINTRIX-INFU>>	/hin/run process
[wiesemann:~/di	fferent-branch-munich/MATRIX1

- I download PDF of this session!
- two options:
  - I. use your own laptop locally

- 2. use your remote ssh login (for Mac/Windoof users highly recommended)
  - \$ ssh bndXXX@bnd01.iihe.ac.be → enter password

🚾 mars — bnd005@bnd01:~ — ssh bnd005@bnd01.iihe.ac.be — 107×44 [**[mars:~]** ssh bnd005@bnd01.iihe.ac.be [bnd005@bnd01.iihe.ac.be's password: Last login: Fri Aug 23 08:01:24 2024 from ip-088-152-010-164.um26.pools.vodafone-ip.de [[bnd005@bnd01 ~]\$ source /cvmfs/sft.cern.ch/lcg/views/setupViews.sh LCG_102 x86_64-centos7-gcc11-opt [bnd005@bnd01 ~]\$

→ need to install LHAPDF from <u>https://lhapdf.hepforge.org/</u> (including the needed PDF set)

(\$ source /cvmfs/sft.cern.ch/lcg/views/setupViews.sh LCG 102 x86  $64-centos7-gcc11-opt \rightarrow$  should not be needed, check: gcc  $--version \rightarrow ||.2.0|$ 







- Idownload & setup MATRIX from <a href="https://matrix.hepforge.org/">https://matrix.hepforge.org/</a>
  - mkdir Matrix tutorial Ş
  - \$ cd Matrix tutorial

  - \$ tar xf MATRIX v2.1.0.tar.gz
  - cd MATRIX v2.1.0/ \$

🚾 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_Tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44 • [[mars:~] ssh bnd005@bnd01.iihe.ac.be [bnd005@bnd01.iihe.ac.be's password: Last login: Fri Aug 23 09:27:38 2024 from ip-088-152-010-164.um26.pools.vodafone-ip.de [[bnd005@bnd01 ~]\$ source /cvmfs/sft.cern.ch/lcg/views/setupViews.sh LCG_102 x86_64-centos7-gcc11-opt [[bnd005@bnd01 ~]\$ mkdir Matrix_Tutorial [[bnd005@bnd01 ~]\$ cd Matrix_Tutorial [[bnd005@bnd01 Matrix_Tutorial]\$ wget https://matrix.hepforge.org/download/MATRIX_v2.1.0.tar.gz --2024-08-23 09:28:51-- https://matrix.hepforge.org/download/MATRIX_v2.1.0.tar.gz ] 64,598,385 18.8MB/s in 3.3s <=> 2024-08-23 09:28:55 (18.8 MB/s) - »MATRIX_v2.1.0.tar.gz« gespeichert [64598385] [[bnd005@bnd01 Matrix_Tutorial]\$ tar xf MATRIX_v2.1.0.tar.gz [[bnd005@bnd01 Matrix_Tutorial]\$ cd MATRIX_v2.1.0/ [bnd005@bnd01 MATRIX_v2.1.0]\$

### \$ wget https://matrix.hepforge.org/download/MATRIX v2.1.0.tar.gz





#### start compilation script

#### ./matrix \$

### task: check list of processes using the script and find short-cut for charge neutral Drell-Yan without decay

answer?

# Hands on !





#### start compilation script

\$ ./matrix

### task: check list of processes using the script and find short-cut for charge neutral Drell-Yan without decay

### answer: the short cut for on-shell Z-boson production is ppz01





#### start compilation script ./matrix \$ >>> list (or just ENTER)



process_id		process		description
 pph21 ppz01 ppw01 ppwx01	>> >> >> >>	p p> H p p> Z p p> W^- p p> W^+	>> >> >> >>	on-shell Higgs production (NNLO) on-shell Z production (NNLO,NLO EW) on-shell W- production with CKM (NNLO) on-shell W+ production with CKM (NNLO)

QCD and Monte Carlo event generators (Lecture 2 – hands-on session)

September 6, 2024



# start compilation script \$ ./matrix >>> list (or just ENTER)

• • •	🛅 mars	s — bnd005@bnd01:/var/bnd/users	s/bnd005/Matrix_tutoria	l/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe	e.ac.be — 107×44
	M. G1 S. Ka M. Wi	cazzini allweit iesemann	( (s (ma	grazzini@physik.uzh.ch)   tefan.kallweit@cern.ch)   rius.wiesemann@cern.ch)   	
	MATR] from by ci	IX is based on a number various people and gro iting the references in	r of different c oups. Please ack n CITATIONS.bib	omputations and tools   nowledge their efforts   created with every run.   /	
<pre>&lt;<matrix-make>&gt; This is the MATRIX process compilation. &lt;<matrix-read>&gt; Type process_id to be compiled and created. Type "list" to show</matrix-read></matrix-make></pre>					
process_id		process		description	
oph21 opz01 opw01 opwx01 opeex02 opeex02 openex02 openex02 opeexa03 opeexa03 opeexa03 openexa03 openexa03 operexa03 operexa03 operexa03 opeexnea03 opezz02 opwxw02 opemexmx04 opeeexex04 opeeexex04 opeeexnmnmx04 opeeexnenex04	~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~	p p> H p p> Z p p> W^ p p> W^++ p p> e^- e^++ p p> e^- v_e^++ p p> e^+ v_e^ p p> gamma gamma p p> e^- e^+ gamma p p> e^- v_e^+ gam p p> e^- v_e^+ gam p p> e^- v_e^+ gam p p> e^- v_e^+ gam p p> Z Z p p> Z Z p p> e^- mu^- e^++ p p> e^- e^+ v_mu^- p p> e^- e^+ v_mu^- p p> e^- e^+ v_mu^- p p> e^- e^+ v_e^-	>> >> >> >> >> >> >> >> >> >> >> >> >>	on-shell Higgs production ( on-shell Z production (NNLO on-shell W- production with on-shell W+ production with Z production with decay (NN Z production with decay (NN W- production with decay an gamma gamma production (NNL Z gamma production with dec Z gamma production with dec W- gamma production with dec W+ gamma production with de w+ gamma production with de on-shell ZZ production (NNL on-shell WW production (NNL ZZ production with decay (N ZZ production with decay (N ZZ/WW production with decay (N	NNLO) , NLO EW) CKM (NNLO) CKM (NNLO) LO, NLO EW) CKM (NNLO, N CKM (NNLO, N CKM (NNLO, N CKM (NNLO, N CKM (NNLO, N CKM (NNLO) CAY (NNLO) C
opeeexnex04 opeexmxnm04 opeexexne04 opttx20 opaaa03  ================	>> >> >> >> >> =>>	p p> e^- e^- e^+ v p p> e^- e^+ mu^+ p p> e^- e^+ e^+ v p p> top anti-top p p> gamma gamma g	/_e^+ >> V_mu^- >> /_e^- >> >> gamma >>	W-2 production with decay ( W+Z production with decay ( W+Z production with decay ( on-shell top-pair productio gamma gamma gamma productio	NNLO,NLO EW) NNLO,NLO EW) NNLO,NLO EW) on (NNLO) on (NNLO)



### start compilation script \$ ./matrix >>> list (or just ENTER)

• • •	🔯 mars	s — bnd005@bnd01:/var/bnd/users/bnd0	05/Matrix_tutoria	I/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44
	M. Gi S. Ka M. Wi	cazzini allweit Lesemann	() (s [.] (ma:	grazzini@physik.uzh.ch)   tefan.kallweit@cern.ch)   rius.wiesemann@cern.ch)   
	MATRI from by ci	IX is based on a number of various people and groups. Iting the references in CIT	different co Please ack ATIONS.bib	omputations and tools   nowledge their efforts   created with every run.   /
<pre>&lt;<matrix-make>&gt; This is the MATRIX process compilation. &lt;<matrix-read>&gt; Type process_id to be compiled and created. Type "list" to show</matrix-read></matrix-make></pre>				
process_id		process		description
onh21	>>	n n> H	>>	on-shell Higgs production (NNLO)
pz01	>>	p p> Z	>>	on-shell Z production (NNLO,NLO EW)
ори01	>>	p p> W^-	>>	on-shell W- production with CKM (NNLO)
opwx01	>>	p p> W^+	>>	on-shell W+ production with CKM (NNLO)
opeex02	>>	p p> e^- e^+	>>	Z production with decay (NNLO,NLO EW)
opnenex02	>>	p p> v_e^- v_e^+	>>	Z production with decay (NNLO,NLO EW)
ppenex02	>>	p p> e^- v_e^+	>>	W- production with decay and CKM (NNLO,N
ppexne02	>>	p p> e^+ v_e^-	>>	W+ production with decay and CKM (NNLO,N
ppaa02	>>	p p> gamma gamma	>>	gamma gamma production (NNLO)
ppeexa03	>>	p p> e^- e^+ gamma	>>	Z gamma production with decay (NNLO)
ppnenexa03	>>	p p> v_e^- v_e^+ gamma	>>	Z gamma production with decay (NNLO)
ppenexa03	>>	p p> e^- v_e^+ gamma	>>	W- gamma production with decay (NNLO)
opexnea03	>>	p p> e^+ v_e^- gamma	>>	W+ gamma production with decay (NNLO)
ppzz02	>>	p p> Z Z	>>	on-shell ZZ production (NNLO)
pwxw02	>>	p p> W^+ W^-	>>	on-shell ww production (NNLO)
opemexmx04	>>	p p> e^- mu^- e^+ mu^+	>>	ZZ production with decay (NNLO,NLO gg,NL
opeeexex04	>>	$p p \rightarrow e^{-} e^{-$	>>	ZZ production with decay (NNLO, NLO gg, NL
opeexnmnmx04	>>	p p> e^- e^+ v_mu^- v_	mu^+ >>	ZZ production with decay (NNLO, NLO gg, NL
opemxnmnex04	>>	$\beta \beta = - \beta e^{-1} mu^{+} v_{-} mu^{-} v$	_e^+ >>	WW production with decay (NNLO, NLO gg, NL
	>>	$p p \longrightarrow q^{-1} q$	^+ >>	ZZ/ww production with decay (NNLO, NLO gg
	>>	$p p = -> e^{-} mu^{-} e^{+} v_{-}mu$	~+ >>	W-Z production with decay (NNLO, NLO EW)
	~~	$p p \longrightarrow e^{-1} e^{-1} e^{-1} e^{-1} e^{-1} e^{-1} e^{-1}$	^_	W+Z production with decay (NNLO, NLO EW)
	~~	$p p = 2 e^{-} e^{+} mu^{+} v_{-}mu^{-}$		W+Z production with decay (NNLO, NLO EW)
$n \pm \frac{1}{2}$	~ ~ ~	$p p \rightarrow e - e + e + v_e = -$		on-shell ton-nair production (NNLO)
	~~~	p p = 2 top anti-top	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	damma damma damma production (NNLO)
=======================================	=>>	pp> ganina ganina ganina		







start compilation script \$./matrix >>> list (or just ENTER) >>> ppz01

💿 🕒 🔵	🔯 mar	rs — bnd005@bnd01:/var/bnd/users/bnd005/Matrix _.	_tutoria	l/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44
ppenexa03	>>	p p> e^- v_e^+ gamma	>>	W- gamma production with decay (NNLO)
ppexnea03	>>	p p> e^+ v_e^- gamma	>>	W+ gamma production with decay (NNLO)
ppzz02	>>	p p> Z Z	>>	on-shell ZZ production (NNLO)
ppwxw02	>>	p p> W^+ W^-	>>	on-shell WW production (NNLO)
ppemexmx04	>>	p p> e^- mu^- e^+ mu^+	>>	ZZ production with decay (NNLO,NLO gg,NL
ppeeexex04	>>	p p> e^- e^- e^+ e^+	>>	ZZ production with decay (NNLO,NLO gg,NL
ppeexnmnmx04	>>	p p> e^- e^+ v_mu^- v_mu^+	>>	ZZ production with decay (NNLO,NLO gg,NL
ppemxnmnex04	>>	p p> e^- mu^+ v_mu^- v_e^+	>>	WW production with decay (NNLO,NLO gg,NL
ppeexnenex04	>>	p p> e^- e^+ v_e^- v_e^+	>>	ZZ/WW production with decay (NNLO,NLO gg
ppemexnmx04	>>	p p> e^- mu^- e^+ v_mu^+	>>	W-Z production with decay (NNLO,NLO EW)
ppeeexnex04	>>	p p> e^- e^- e^+ v_e^+	>>	W-Z production with decay (NNLO,NLO EW)
ppeexmxnm04	>>	p p> e^- e^+ mu^+ v_mu^-	>>	W+Z production with decay (NNLO,NLO EW)
ppeexexne04	>>	p p> e^- e^+ e^+ v_e^-	>>	W+Z production with decay (NNLO,NLO EW)
ppttx20	>>	p p> top anti-top	>>	on-shell top-pair production (NNLO)
ppaaa03	>>	p p> gamma gamma gamma	>>	gamma gamma gamma production (NNLO)
r I		04		

=========>> ppz01






start compilation script

- \$./matrix
- >>> list (or just ENTER)
- >>> ppz01
- >>> y...y...



• • •	💿 mars	- bnd005@bnd01:/var/bnd/users/bnd005/Matrix	_tutoria	I/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44
ppenexa03	>>	p p> e^- v_e^+ gamma	>>	W- gamma production with decay (NNLO)
ppexnea03	>>	p p> e^+ v_e^- gamma	>>	W+ gamma production with decay (NNLO)
ppzz02	>>	p p> Z Z	>>	on-shell ZZ production (NNLO)
ppwxw02	>>	p p> W^+ W^-	>>	on-shell WW production (NNLO)
ppemexmx04	>>	p p> e^- mu^- e^+ mu^+	>>	ZZ production with decay (NNLO,NLO gg,NL
ppeeexex04	>>	p p> e^- e^- e^+ e^+	>>	ZZ production with decay (NNLO,NLO gg,NL
ppeexnmnmx04	>>	p p> e^- e^+ v_mu^- v_mu^+	>>	ZZ production with decay (NNLO,NLO gg,NL
ppemxnmnex04	>>	p p> e^- mu^+ v_mu^- v_e^+	>>	WW production with decay (NNLO,NLO gg,NL
ppeexnenex04	>>	p p> e^- e^+ v_e^- v_e^+	>>	ZZ/WW production with decay (NNLO,NLO gg
ppemexnmx04	>>	p p> e^- mu^- e^+ v_mu^+	>>	W-Z production with decay (NNLO,NLO EW)
ppeeexnex04	>>	p p> e^- e^- e^+ v_e^+	>>	W-Z production with decay (NNLO,NLO EW)
ppeexmxnm04	>>	p p> e^- e^+ mu^+ v_mu^-	>>	W+Z production with decay (NNLO,NLO EW)
ppeexexne04	>>	p p> e^- e^+ e^+ v_e^-	>>	W+Z production with decay (NNLO,NLO EW)
ppttx20	>>	p p> top anti-top	>>	on-shell top-pair production (NNLO)
ppaaa03	>>	p p> gamma gamma gamma	>>	gamma gamma gamma production (NNLO)
[] =======;	>> pp	z01		
< <matrix-make></matrix-make>	>> MA	TRIX usage agreements:		
< <matrix-make></matrix-make>	>> MA	TRIX is based on several computa	tions	, studies and tools from
	va	rious people and groups. When us	ing r	esults obtained by MATRIX
	th	nese efforts must be acknowledged	by c	iting the list of
	re	ferences in the CITATION.bib fil	.e, wh:	ich is created in the
	re	sult folder with every run.		
< <matrix-read< td=""><td>>> Dc</td><td>you agree with these terms? Typ</td><td>e "y"</td><td>to agree, or "n" to</td></matrix-read<>	>> Dc	you agree with these terms? Typ	e "y"	to agree, or "n" to
	ab	ort the code.	-	
[]=====================================	>> y			
< <matrix-make></matrix-make>	>> Th	is compilation of MATRIX uses di	rectl	y the code OpenLoops from
	ht	tp://openloops.hepforge.org by F	. Buc	cioni, F. Cascioli, JN.
	La	ng, J. Lindert, P. Maierhoefer,	S. Po:	zzorini, H. Zhang, M.
	Zc	oller. You have to cite the relav	ant r	eferences in
	CI	TATIONS.bib, when using results	obtai	ned with this
	ir	stallation.		
< <matrix-read></matrix-read>	>> Dc	you agree with these terms? Typ	e "y"	to agree, or "n" to
	ab	ort the code.		
[=====================================	>> y			
< <matrix-make></matrix-make>	>> Yc	ou have agreed with all MATRIX us	age t	erms.
< <matrix-make></matrix-make>	>> Cr	reating input files for process p	pz01 :	inside folder /var/bnd/us
	er	s/bnd005/Matrix_tutorial/MATRIX_	v2.1.	0/run/input_files/ppz01
< <matrix-make></matrix-make>	>> St	arting compilation		
< <matrix-error< td=""><td>R>> N</td><td>lo installation of LHAPDF found.</td><td>Insta</td><td>ll LHAPDF such that</td></matrix-error<>	R>> N	lo installation of LHAPDF found.	Insta	ll LHAPDF such that
	1	hapdf-config executable is found	unde	r your environmental
	\$	PATH variable or specify path to	lhap	df-config under
	I	path_to_lhapdf" in MATRIX_config	urati	on file.
[bnd0050bnd01	MATE	XIX_v2.1.0]\$		





open MATRIX_configuration file and add path to LHAPDF (or lhapdf config has to recognized/in **\$PATH** variable)

\$ emacs -nw config/ MATRIX configuration ar/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

[bnd005@bnd01 MATRIX_v2.1.0]\$ emacs -nw config/MATRIX_configuration







open MATRIX_configuration file and add path to LHAPDF (or lhapdf_config has to recognized/in \$PATH variable)

\$ emacs -nw config/ MATRIX_configuration

```
mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44
• • •
File Edit Options Buffers Tools Help
# MATRIX configuration file #
# This file contains all parameters to configure MATRIX
# In the run_folders this is the link to the central configuration file
# in MATRIX/config/; you can replace the link by a copy to have individual
# configurations for the different processes
# Editor to be used to edit input files from MATRIX shell
# (default: use the one specified under environmental variable EDITOR)
#default_editor = emacs # eg, emacs, vi, nano, ...
# runmode of MATRIX: 0 -- multicore (default)
                    1 -- cluster
mode = 0
###=============####
## cluster parameter ##
###===============####
# Name of cluster currently supported:
   slurm, LSF (eg, lxplus), HTcondor, condor_lxplus (special version working on lxplus HTCondor),
  condor, PBS, Torque, SGE (PSB and Torque/OpenPBS are identical at the moment)
cluster_name = slurm
# Queue/Partition of cluster to be used for running
#cluster_queue = 2nw
# Use local scratch directory to run on cluster (speedup for slow shared file systems):
# 0 -- standard run on shared file system (default)
# 1 -- run in local scratch of nodes; PROVIDE cluster_local_scratch_path BELOW!
# NOT IMPLEMENTED YET: 2 -- run without shared file system; PROVIDE cluster_local_scratch_path BELOW!
cluster_local_run = 0
# Provide a path to the local scratch directories of the nodes
#cluster_local_scratch_path = /PATH/TO/SCRATCH/
# Maximal runtime for a single process on a single node,
# too low values may lead failure of the code
#cluster_runtime = 2-00:00:00
# add customizable lines at the beginning of cluster submission file
-UU-:---F1 MATRIX_configuration Top L1
                                              (Fundamental) ----
For information about GNU Emacs and the GNU system, type C-h C-a.
```



• • •

- open MATRIX_configuration file and add path to LHAPDF (or lhapdf_config has to recognized/in \$PATH variable)
 - \$ emacs -nw config/ MATRIX_configuration
 - > Ctrl-v (or arrows to scroll down)

🔤 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

###========================####
compilation parameter
###======================####

maximum number of cores used for compilation (default: maximal cores available on the machine); nr_cores = 4 # when commented the default is used

you can specify the path to lhapdf-config executable; not required if lhapdf-config executable
accessible from command line (will be determined automatically in that case)
#path_to_lhapdf = /PATH/lhapdf-config # !absolute path!

if OpenLoops is already installed, you can specify the path to openloops executable; not required
if openloops executable accessible from command line (will be determined automatically in that case);
otherwise, OpenLoops will be downloaded and installed automatically
#path_to_openloops = /PATH/openloops # !absolute path!

#you can specify the path to recola, if already installed locally.
#path_to_recola = /PATH/recola_sm # !absolute path!

#you can specify the path to chaplin, if already installed locally.
#path_to_chaplin = /PATH/chaplin # !absolute path!

you can specify the path to ginac, if already installed locally; ginac will not be compiled in this case
#path_to_ginac = /PATH/ginac-install/ # !absolute path!

you can specify the path to cln, if already installed locally; cln will not be compiled in this case
#path_to_cln = /PATH/cln-install/ # !absolute path!

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

you can specify the path to the libfortran libary, usually found by the system automatically
NOTE: this path must also be set if the libquadmath library is not found
NOTE: this path can be also used if other libaries are missing during the compilation process
#path_to_libgfortran = /PATH/x86_64-linux-gnu/ # !absolute path!

you can specify the path to gsl-config executable; not required if gsl-config executable # accessible from command line (will be determined automatically in that case) #path_to_gsl = /PATH/gsl-config # !absolute path!

-UU-:---F1 MATRIX_configuration Bot L91

(Fundamental) -----





• • •

- open MATRIX_configuration file and add path to LHAPDF (or lhapdf-config has to recognized/in \$PATH variable)
 - \$ emacs -nw config/ MATRIX_configuration
 - > Ctrl-v (or arrows to scroll down)
 - > path_to_lhapdf = /var/bnd/
 theo/LHAPDF-6.5.4/bin/
 lhapdf-config (set)

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

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accessible from command line (will be determined automatically in that case)
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if OpenLoops is already installed, you can specify the path to openloops executable; not required # if openloops executable accessible from command line (will be determined automatically in that case); # otherwise, OpenLoops will be downloaded and installed automatically #path_to_openloops = /PATH/openloops # !absolute path!

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#path_to_ginac = /PATH/ginac-install/ # !absolute path!

you can specify the path to cln, if already installed locally; cln will not be compiled in this case
#path_to_cln = /PATH/cln-install/ # !absolute path!

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

you can specify the path to the libfortran libary, usually found by the system automatically
NOTE: this path must also be set if the libquadmath library is not found
NOTE: this path can be also used if other libaries are missing during the compilation process
#path_to_libgfortran = /PATH/x86_64-linux-gnu/ # !absolute path!

you can specify the path to gsl-config executable; not required if gsl-config executable
accessible from command line (will be determined automatically in that case)
#path_to_gsl = /PATH/gsl-config # !absolute path!





• • •

- open MATRIX_configuration file and add path to LHAPDF (or lhapdf-config has to recognized/in \$PATH variable)
 - \$ emacs -nw config/ MATRIX_configuration
 - > Ctrl-v (or arrows to scroll down)
 - > path_to_lhapdf = /var/bnd/
 theo/LHAPDF-6.5.4/bin/
 lhapdf-config (set)
 - > Ctrl-x Ctrl-s (to save)

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

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you can specify the path to cln, if already installed locally; cln will not be compiled in this case
#path_to_cln = /PATH/cln-install/ # !absolute path!

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

you can specify the path to the libfortran libary, usually found by the system automatically
NOTE: this path must also be set if the libquadmath library is not found
NOTE: this path can be also used if other libaries are missing during the compilation process
#path_to_libgfortran = /PATH/x86_64-linux-gnu/ # !absolute path!

you can specify the path to gsl-config executable; not required if gsl-config executable
accessible from command line (will be determined automatically in that case)
#path_to_gsl = /PATH/gsl-config # !absolute path!



42

while we are at it, also set the following other paths to speed up compilation

> path_to_openloops = /var/ bnd/theo/OpenLoops/openloops

> path_to_chaplin = /var/ bnd/theo/chaplin-1.2/install

> path_to_ginac = /var/bnd/
theo/ginac-1.8.7/install

> path_to_cln = /var/bnd/
theo/cln-1.3.7/install

🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

###===========####
compilation parameter
###=================####

maximum number of cores used for compilation (default: maximal cores available on the machine); nr_cores = 4 # when commented the default is used

you can specify the path to lhapdf-config executable; not required if lhapdf-config executable
accessible from command line (will be determined automatically in that case)
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if OpenLoops is already installed, you can specify the path to openloops executable; not required # if openloops executable accessible from command line (will be determined automatically in that case); # otherwise, OpenLoops will be downloaded and installed automatically path_to_openloops = /var/bnd/theo/OpenLoops/openloops

#you can specify the path to recola, if already installed locally.
#path_to_recola = /PATH/recola_sm # !absolute path!

#you can specify the path to chaplin, if already installed locally.
path_to_chaplin = /var/bnd/theo/chaplin-1.2/install

you can specify the path to ginac, if already installed locally; ginac will not be compiled in this case
path_to_ginac = /var/bnd/theo/ginac-1.8.7/install/

you can specify the path to cln, if already installed locally; cln will not be compiled in this case
path_to_cln = /var/bnd/theo/cln-1.3.7/install

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

you can specify the path to the libfortran libary, usually found by the system automatically
NOTE: this path must also be set if the libquadmath library is not found
NOTE: this path can be also used if other libaries are missing during the compilation process
#path_to_libgfortran = /PATH/x86_64-linux-gnu/ # !absolute path!

you can specify the path to gsl-config executable; not required if gsl-config executable
accessible from command line (will be determined automatically in that case)
#path_to_gsl = /PATH/gsl-config # !absolute path!



43

while we are at it also set the following other paths to speed up compilation

> path_to_openloops = /var/ bnd/theo/OpenLoops/openloops

> path_to_chaplin = /var/ bnd/theo/chaplin-1.2/install

- > path_to_ginac = /var/bnd/
 theo/ginac-1.8.7/install
- > path_to_cln = /var/bnd/
 theo/cln-1.3.7/install

task: limit number of cores to 8 (to avoid overloading)

answer?

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

###===========####
compilation parameter
###=================####

maximum number of cores used for compilation (default: maximal cores available on the machine); nr_cores = 4 # when commented the default is used

you can specify the path to lhapdf-config executable; not required if lhapdf-config executable
accessible from command line (will be determined automatically in that case)
path_to_lhapdf = /var/bnd/theo/LHAPDF-6.5.4/bin/lhapdf-config

if OpenLoops is already installed, you can specify the path to openloops executable; not required
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#you can specify the path to chaplin, if already installed locally.
#path_to_chaplin = /PATH/chaplin # !absolute path!

you can specify the path to ginac, if already installed locally; ginac will not be compiled in this case
#path_to_ginac = /PATH/ginac-install/ # !absolute path!

you can specify the path to cln, if already installed locally; cln will not be compiled in this case
#path_to_cln = /PATH/cln-install/ # !absolute path!

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

you can specify the path to the libfortran libary, usually found by the system automatically
NOTE: this path must also be set if the libquadmath library is not found
NOTE: this path can be also used if other libaries are missing during the compilation process
#path_to_libgfortran = /PATH/x86_64-linux-gnu/ # !absolute path!

you can specify the path to gsl-config executable; not required if gsl-config executable # accessible from command line (will be determined automatically in that case) #path_to_gsl = /PATH/gsl-config # !absolute path!



- while we are at it also set the following other paths to speed up compilation
 - > path_to_openloops = /var/ bnd/theo/OpenLoops/openloops
 - > path_to_chaplin = /var/ bnd/theo/chaplin-1.2/install
 - > path_to_ginac = /var/bnd/
 theo/ginac-1.8.7/install
 - > path_to_cln = /var/bnd/
 theo/cln-1.3.7/install

task: limit number of cores to 8
 (to avoid overloading)

answer: set $nr_cores = 8$

📀 😑 💼 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

###===========####
compilation parameter
###=================###

maximum number of cores used for compilation (default: maximal cores available on the machine); nr_cores = 8 # when commented the default is used

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#path_to_recola = /PATH/recola_sm # !absolute path!

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#path_to_chaplin = /PATH/chaplin # !absolute path!

you can specify the path to ginac, if already installed locally; ginac will not be compiled in this case
#path_to_ginac = /PATH/ginac-install/ # !absolute path!

you can specify the path to cln, if already installed locally; cln will not be compiled in this case
path_to_cln = /var/bnd/theo/cln-1.3.7/install

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

you can specify the path to the libfortran libary, usually found by the system automatically
NOTE: this path must also be set if the libquadmath library is not found
NOTE: this path can be also used if other libaries are missing during the compilation process
#path_to_libgfortran = /PATH/x86_64-linux-gnu/ # !absolute path!

you can specify the path to gsl-config executable; not required if gsl-config executable # accessible from command line (will be determined automatically in that case) #path_to_gsl = /PATH/gsl-config # !absolute path!

-UU-:---F1 MATRIX_configuration

tion Bot L91

(Fundamental) -----



while we are at it also set the following other paths to speed up compilation

> path_to_openloops = /var/ bnd/theo/OpenLoops/openloops

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 theo/ginac-1.8.7/install
- > path_to_cln = /var/bnd/
 theo/cln-1.3.7/install

 $> nr_cores = 8$

📀 😑 💼 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

###===========####
compilation parameter
###=================###

maximum number of cores used for compilation (default: maximal cores available on the machine); nr_cores = 8 # when commented the default is used

you can specify the path to lhapdf-config executable; not required if lhapdf-config executable
accessible from command line (will be determined automatically in that case)
path_to_lhapdf = /var/bnd/theo/LHAPDF-6.5.4/bin/lhapdf-config

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#you can specify the path to chaplin, if already installed locally.
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you can specify the path to ginac, if already installed locally; ginac will not be compiled in this case
#path_to_ginac = /PATH/ginac-install/ # !absolute path!

you can specify the path to cln, if already installed locally; cln will not be compiled in this case
path_to_cln = /var/bnd/theo/cln-1.3.7/install

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

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-UU-:---F1 MATRIX_configuration

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(Fundamental) -----





- while we are at it also set the following other paths to speed up compilation
 - > path_to_openloops = /var/ bnd/theo/OpenLoops/openloops
 - > path_to_chaplin = /var/ bnd/theo/chaplin-1.2/install
 - > path_to_ginac = /var/bnd/
 theo/ginac-1.8.7/install
 - > path_to_cln = /var/bnd/
 theo/cln-1.3.7/install
 - $> nr_cores = 8$
 - > Ctrl-x Ctrl-s (to save)

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

###===========####
compilation parameter
###=================####

maximum number of cores used for compilation (default: maximal cores available on the machine); nr_cores = 4 # when commented the default is used

you can specify the path to lhapdf-config executable; not required if lhapdf-config executable
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#path_to_openloops = /PATH/openloops # !absolute path!

#you can specify the path to recola, if already installed locally.
#path_to_recola = /PATH/recola_sm # !absolute path!

#you can specify the path to chaplin, if already installed locally.
#path_to_chaplin = /PATH/chaplin # !absolute path!

you can specify the path to ginac, if already installed locally; ginac will not be compiled in this case
#path_to_ginac = /PATH/ginac-install/ # !absolute path!

you can specify the path to cln, if already installed locally; cln will not be compiled in this case
#path_to_cln = /PATH/cln-install/ # !absolute path!

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

you can specify the path to the libfortran libary, usually found by the system automatically
NOTE: this path must also be set if the libquadmath library is not found
NOTE: this path can be also used if other libaries are missing during the compilation process
#path_to_libgfortran = /PATH/x86_64-linux-gnu/ # !absolute path!

you can specify the path to gsl-config executable; not required if gsl-config executable # accessible from command line (will be determined automatically in that case) #path_to_gsl = /PATH/gsl-config # !absolute path!



47

- while we are at it also set the following other paths to speed up compilation
 - > path_to_openloops = /var/ bnd/theo/OpenLoops/openloops
 - > path_to_chaplin = /var/ bnd/theo/chaplin-1.2/install
 - > path_to_ginac = /var/bnd/
 theo/ginac-1.8.7/install
 - > path_to_cln = /var/bnd/
 theo/cln-1.3.7/install
 - $> nr_cores = 8$
 - > Ctrl-x Ctrl-s (to save)
 - > Ctrl-x Ctrl-c (to close the file)

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

###===========####
compilation parameter
###==================####

maximum number of cores used for compilation (default: maximal cores available on the machine); nr_cores = 4 # when commented the default is used

you can specify the path to lhapdf-config executable; not required if lhapdf-config executable
accessible from command line (will be determined automatically in that case)
path_to_lhapdf = /var/bnd/theo/LHAPDF-6.5.4/bin/lhapdf-config

if OpenLoops is already installed, you can specify the path to openloops executable; not required
if openloops executable accessible from command line (will be determined automatically in that case);
otherwise, OpenLoops will be downloaded and installed automatically
#path_to_openloops = /PATH/openloops # !absolute path!

#you can specify the path to recola, if already installed locally.
#path_to_recola = /PATH/recola_sm # !absolute path!

#you can specify the path to chaplin, if already installed locally.
#path_to_chaplin = /PATH/chaplin # !absolute path!

you can specify the path to ginac, if already installed locally; ginac will not be compiled in this case
#path_to_ginac = /PATH/ginac-install/ # !absolute path!

you can specify the path to cln, if already installed locally; cln will not be compiled in this case
#path_to_cln = /PATH/cln-install/ # !absolute path!

you can specify the path to 2loop amplitude of ppaaa03 process, if already installed locally;
#path_to_ppaaa03_2loop = /PATH/ppaaa03_2loop-install/ # !absolute path!

you can specify the path to the libfortran libary, usually found by the system automatically
NOTE: this path must also be set if the libquadmath library is not found
NOTE: this path can be also used if other libaries are missing during the compilation process
#path_to_libgfortran = /PATH/x86_64-linux-gnu/ # !absolute path!

you can specify the path to gsl-config executable; not required if gsl-config executable # accessible from command line (will be determined automatically in that case) #path_to_gsl = /PATH/gsl-config # !absolute path!





- while we are at it also set the following other paths to speed up compilation
 - > path_to_openloops = /var/ bnd/theo/OpenLoops/openloops
 - > path_to_chaplin = /var/ bnd/theo/chaplin-1.2/install
 - > path_to_ginac = /var/bnd/
 theo/ginac-1.8.7/install
 - > path_to_cln = /var/bnd/
 theo/cln-1.3.7/install
 - $> nr_cores = 8$
 - > Ctrl-x Ctrl-s (to save)
 - > Ctrl-x Ctrl-c (to close the file)

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44

[bnd005@bnd01 MATRIX_v2.1.0]\$ emacs -nw config/MATRIX_configuration [bnd005@bnd01 MATRIX_v2.1.0]\$



while we are at it also set the following other paths to speed up compilation

> path to openloops = /var/ bnd/theo/OpenLoops/openloops

> path to chaplin = /var/ bnd/theo/chaplin-1.2/install



[bnd005@bnd01 MATRIX_v2.1.0]\$ emacs -nw config/MATRIX_configuration [bnd005@bnd01 MATRIX_v2.1.0]\$





- now let's retry the compilation of the ppz01 process either like before or just one line without needing to agree again to the terms
 - ./matrix ppz01 --agree



QCD and Monte Carlo event generators (Lecture 2 — hands-on session)



- now let's retry the compilation of the ppz01 process either like before or just one line without needing to agree again to the terms
 - > ./matrix ppz01 --agree



Marius Wiesemann (MPP Munich)

🕐 🕒 🌒 💼 n	nars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×4
< <matrix-make>></matrix-make>	result folder with every run. This compilation of MATRIX uses directly the code OpenLoops from http://openloops.hepforge.org by F. Buccioni, F. Cascioli, JN. Lang, J. Lindert, P. Maierhoefer, S. Pozzorini, H. Zhang, M. Zoller. You have to cite the relavant references in CITATIONS.bib, when using results obtained with this
< <matrix-make>> <<matrix-make>></matrix-make></matrix-make>	You have agreed with all MATRIX usage terms. Creating input files for process ppz01 inside folder /var/bnd/us ers/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/input_files/ppz01
< <matrix-make>> <<matrix-make>></matrix-make></matrix-make>	Starting compilation Using compiled LHAPDF installation under (config/MATRIX_configuration) path_to_lbapdf=/var/bpd/tbeo/LHAPDE-6.5.4/bin/lbapdf-config
< <matrix-make>></matrix-make>	Download and Compilation of OpenLoops via git clone -b public_beta https://gitlab.com/openloops/OpenLoops.git into /var /bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/OpenLoo ps-install
< <matrix-make>></matrix-make>	Downloading OpenLoops
< <matrix-make>> <<matrix-make>></matrix-make></matrix-make>	Compiling OpenLoops Extracting and Compiling Chaplin from /var/bnd/users/bnd005/Matr ix_tutorial/MATRIX_v2.1.0/external/chaplin-1.2.tar into /var/bnd /users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/chaplin- install
< <matrix-make>></matrix-make>	Extracting and Compiling Cln from /var/bnd/users/bnd005/Matrix_t utorial/MATRIX_v2.1.0/external/cln-1.3.4.tar into /var/bnd/users /bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/cln-install
< <matrix-make>></matrix-make>	Extracting and Compiling Ginac from /var/bnd/users/bnd005/Matrix _tutorial/MATRIX_v2.1.0/external/ginac-1.6.2.tar into /var/bnd/u sers/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/ginac- install
< <matrix-make>></matrix-make>	Compiling process <ppz01>, this may take a while (see make.log file to monitor the progress)</ppz01>
< <matrix-make>></matrix-make>	Downloading and compiling ppvj amplitude with OpenLoops
< <matrix-make>></matrix-make>	Downloading and compiling ppvj_ew amplitude with OpenLoops
< <matrix-make>></matrix-make>	Creating process folder in "run"-directory: "/var/bnd/users/bnd0 05/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX"
< <matrix-info>></matrix-info>	Process folder successfully created.
< <matrix-info>></matrix-info>	Process generation finished, to go to the run directory type:
	cd /var/bhd/users/bhd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX
< <matrix-infu>></matrix-infu>	/bin/run process
[bnd005@bnd01 M/	ATRIX_v2.1.0]\$





- now let's retry the compilation of the ppz01 process either like before or just one line without needing to agree again to the terms
 - > ./matrix ppz01 --agree



Marius Wiesemann (MPP Munich)

🔍 🕒 🔵 👘 r	nars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×44
< <matrix-make>></matrix-make>	result folder with every run. This compilation of MATRIX uses directly the code OpenLoops from http://openloops.hepforge.org by F. Buccioni, F. Cascioli, JN. Lang, J. Lindert, P. Maierhoefer, S. Pozzorini, H. Zhang, M. Zoller. You have to cite the relavant references in CITATIONS.bib, when using results obtained with this installation.
< <matrix-make>> <<matrix-make>></matrix-make></matrix-make>	You have agreed with all MATRIX usage terms. Creating input files for process ppz01 inside folder /var/bnd/us ers/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/input_files/ppz01
< <matrix-make>> <<matrix-make>></matrix-make></matrix-make>	Starting compilation Using compiled LHAPDF installation under (config/MATRIX_configuration) path_to_lhapdf=/var/bnd/theo/LHAPDF-6.5.4/bin/lhapdf-config
< <matrix-make>></matrix-make>	Download and Compilation of OpenLoops via git clone –b

If you have trouble finishing the compilation, you can execute a bash file with the full solution that does the compilation for you from here:

/var/bnd/theo/help/solution-1-compiliation.sh

	/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/cln-install
< <matrix-make>></matrix-make>	Extracting and Compiling Ginac from /var/bnd/users/bnd005/Matrix
	_tutorial/MATRIX_v2.1.0/external/ginac-1.6.2.tar into /var/bnd/u
	sers/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/ginac-
	install
< <matrix-make>></matrix-make>	Compiling process <ppz01>, this may take a while</ppz01>
	(see make.log file to monitor the progress)
< <matrix-make>></matrix-make>	Downloading and compiling ppvj amplitude with OpenLoops
< <matrix-make>></matrix-make>	Downloading and compiling ppvj_ew amplitude with OpenLoops
< <matrix-make>></matrix-make>	Creating process folder in "run"-directory: "/var/bnd/users/bnd0
	05/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX"
< <matrix-info>></matrix-info>	Process folder successfully created.
< <matrix-info>></matrix-info>	Process generation finished, to go to the run directory type:
	cd /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX
< <matrix-info>></matrix-info>	and start run by typing:
	./bin/run_process
[bnd005@bnd01 M/	ATRIX_v2.1.0]\$





- After changing into the run directory we start the run script
- \$./bin/run_process

- After changing into the run directory we start the run script
- \$./bin/run_process
- First, choose a name for the run:
 |===>> run_my_first_ZZ

[[wiesemann:~/different-branch-munich/MATRIX/run/ppeeexex04_MATRIX] ./bin/run_process /------MATRIX: A fully-differential NNLO(+NNLL) process library \\ // \\ // $|| \rangle \rangle$ // \\ $11 \times$ // \\ Version: 1.0.0.release_candidate4 Aug 2017 Munich -- the MUlti-chaNnel Integrator at swiss (CH) precision --Automates qT-subtraction and Resummation to Integrate X-sections)==== +)==== +)==== + |)==== + |-)==== M. Grazzini (grazzini@physik.uzh.ch) S. Kallweit (stefan.kallweit@cern.ch) M. Wiesemann (marius.wiesemann@cern.ch) MATRIX is based on a number of different computations and tools from various people and groups. Please acknowledge their efforts by citing the list of references which is created with every run. <<MATRIX-READ>> Type name of folder for this run (has to start with "run_"). "ENTER" to create and use "run_01". Press TAB or type "list" to show existing runs. Type "exit" or "quit" to stop. Any other folder will be created.

|=========>> run_my_first_ZZ

- After changing into the run directory we start the run script
- \$./bin/run_process
- First, choose a name for the run:

|===>> run_my_first_ZZ

- The MATRIX run shell has many options, eg, modify input files typing:
- |===>> parameter
- |===>> model
- |===>> distribution

[[wiesemann:~/different-branch-munich/MATRIX/run/ppeeexex04_MATRIX] ./bin/run_process /-----MATRIX: A fully-differential NNLO(+NNLL) process library \\ // / \ \/ || | |_| | \\ // // \\ $|| \rangle \rangle$ // \\ Version: 1.0.0.release_candidate4 Aug 2017 Munich -- the MUlti-chaNnel Integrator at swiss (CH) precision --Automates qT-subtraction and Resummation to Integrate X-sections)==== +)==== +)==== + |)==== + |-)==== M. Grazzini (grazzini@physik.uzh.ch) S. Kallweit (stefan.kallweit@cern.ch) M. Wiesemann (marius.wiesemann@cern.ch) MATRIX is based on a number of different computations and tools from various people and groups. Please acknowledge their efforts by citing the list of references which is created with every run. ---------------/ <<MATRIX-READ>> Type name of folder for this run (has to start with "run_"). "ENTER" to create and use "run_01". Press TAB or type "list" to show existing runs. Type "exit" or "quit" to stop. Any other folder will be created. ==========>> run_my_first_ZZ <<MATRIX-READ>> Type one of the following commands: ("TAB" for auto-completion) General commands description help >> Show help menu. help <command> >> Show help message for specific <command>. >> List available commands again. list exit >> Stop the code. quit Stop the code. >> Input to modify description >> Modify "parameter.dat" input file in editor. parameter >> Modify "model.dat" input file in editor. model Modify "distribution.dat" input file in editor. distribution >> Run-mode to start description >> Start cross section computation in standard mode. run_grid >> Start only grid setup phase. >> Start only extrapolation (grid must be already done). run_pre run_pre_and_main >> Start after grid setup (grid must be already done). >> Start only main run (other runs must be already done). run main run_results >> Start only result combination. run_gnuplot Start only gnuplotting the results. >> >> Setup the run folder, but not start running. setup_run delete_run Remove run folder (including input/log/result). >> tar_run Create <run_folder>.tar (including input/log/result). >> ========>> parameter ========>> model ========>> distribution

How to run # MATRIX if

- After changing into the rwe start the run script
- \$./bin/run_proces
- First, choose a name for

===>> run_my_firs

- The MATRIX run shell l options, eg, modify input
- |===>> parameter

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Solution of the start the run script How to run How to run

- \$./bin/run_proces
- First, choose a name for
 |==>> run my firs
- The MATRIX run shell l options, eg, modify input

===>> parameter

> adjust scales
scale_fact = 91.1876
scale ren = 91.1876

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- After changing into the r we start the run script
- \$./bin/run_proces
- First, choose a name for
 |==>> run my firs
- The MATRIX run shell l options, eg, modify input

===>> parameter

adjust scales
scale_fact = 91.1876
scale_ren = 91.1876
adjust precision at LO
precision LO = 1.e-3

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- After changing into the r we start the run script
- \$./bin/run_proces
- First, choose a name for
 |==>> run my firs
- The MATRIX run shell l options, eg, modify input

===>> parameter

adjust scales
scale_fact = 91.1876
scale_ren = 91.1876
adjust precision at LO
precision_LO = 1.e-3
turn on NLO/NNLO
run_(N)NLO = 1

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How to run define_pT

- After changing into the rwe start the run script
- \$./bin/run_proces n_observed_min pclep = 1.e99 n_observed_min pclep = n_observed_max pclep =
- First, choose a name for
 # Blocks with user-def
 # Mandatory cuts for
 # -- (user_switch M_let
 # Z-boson reconstruct
 user_switch lepton_ide
 User_switch M_Zrec = 2
 user_cut min M_Zrec = 2
- The MATRIX run shell
 User_switch M_leplep_05
 User_cut min_M_leplep_05
 Options, eg, modify input

===>> parameter

adjust scales
 scale_fact = 91.1876
 scale_ren = 91.1876
 adjust precision at LO
 precision_LO = 1.e-3
 turn on NLO/NNLO
 run_(N)NLO = 1
 set rough run-time estimate
 max_time_per_job

Negatively-charged lepto efine pT nclep = 7 lefine eta nclep = 2.7 define_y nclep = 1.e99 _observed_min nclep observed max nclep Positively-charged lept lefine_pT pclep = 7 efine_eta_pclep = 2.7 lefine_y pclep = 1.e99 Blocks with user-define Mandatory cuts for this Z-boson reconstruction user_switch lepton_identi user_cut min_M_Zrec = 66 user_cut max_M_Zrec = 116 user_switch M_leplep_OSSF user_cut min_M_leplep_OSS user_switch R_leplep = user_switch pT_lep_1st = user_cut min_pT_lep_1st = user_switch pT_lep_2nd = ser_cut min_pT_lep_2nd ser_switch M_4lep = ser_cut min_M_4lep = 120 iser_cut max_M_4lep = 130 user_cut min_delta_M_4lep user_cut max_delta_M_4lep user_switch lep_iso = 0 user_cut lep_iso_delta_@ user_cut lep_iso_epsilon - - - - - - - - - - - - - - / MATRIX behavior ----/ nax_time_per_job = 12 switch_distribution = 1 ve_previous_result = 1 save_previous_log = 0 #include_pre_in_results = reduce_workload = 0 $random_seed = 0$ -UU-:**--F1 parameter.dat

[[wiese	emann:~/munich-http/MATRIX/run/ppeeexex04_MATRIX] ./bin/run_process	
	/ I MATRIX: A fully-differential NNLO(+NNLL) process library	- \ I
	Inviter A fully afficient aneo((anel)) process fibrary	
rec # rec # rec # rec # min # max	quirement on negatively-charged lepton transverse momentum (lower cut) quirement on negatively-charged lepton pseudo-rapidity (upper cut) quirement on negatively-charged lepton rapidity (upper cut) nimal number of observed negatively-charged leptons (with cuts above) ximal number of observed negatively-charged leptons (with cuts above)	
n cuts # rec # rec # rec # min # max	<pre>quirement on positively-charged lepton transverse momentum (lower cut) quirement on positively-charged lepton pseudo-rapidity (upper cut) quirement on positively-charged lepton rapidity (upper cut) nimal number of observed positively-charged leptons (with cuts above) ximal number of observed positively-charged leptons (with cuts above)</pre>	
cuts (only process (er _OSSF AND (y used if defined in 'MATRIX/prc/\$process/user/specify.cuts.cxx') nsure IR safety): user_cut min_M_leplep_OSSF) OR (user_switch R_leplep AND user_cut min_R_leple)	
cation = 1	1 # switch to identify leptons from Z-bosons; (0) off (1) ATLAS (2) CMS	
# sw # rec # rec	itch for invariant mass cut on reconstructed Z-bosons; requires: lepton_ident quirement on reconstructed Z-boson invariant mass (lower cut) quirement on reconstructed Z-boson invariant mass (upper cut)	 -
=0 # swi =0 # rec	itch to turn on (1) and off (0) cuts on OSSF lepton-lepton invariant mass quirement on OSSF lepton-lepton invariant mass (lower cut) to ensure IR safet	 -/
# swi 2 # rec	itch to turn on (1) and off (0) cuts on lepton-lepton separation quirement on lepton-lepton separation in y-phi-plane (lower cut)	0
# sw) # rec	itch to turn on (1) and off (0) cuts on pT of hardest lepton quirement on pT of hardest lepton (lower cut)	
# sw1) # rec	n) itch to turn on (1) and off (0) cuts on pT of second-hardest lepton quirement on pT of second-hardest lepton (lower cut))
# sw [*] # red # red = 1.e99 # = 0 #	itch to turn on (1) and off (0) cuts on invariant of 4-lepton system quirement on invariant mass of 4-lepton system (lower cut) quirement on invariant mass of 4-lepton system (upper cut) minimal difference of 4-lepton invariant mass to PDG Z mass maximal difference of 4-lepton invariant mass to PDG Z mass	
# sw ⁺ 0.4 # lep 0.4 # lep	itch to turn on (1) and off (0) isolation between leptons pton isolation cone size pton isolation threshold ratio	
# ver # unr # not #	ry rough time(hours) one main run job shall take (default: 24h) reliable when < 1h, use as tuning parameter for degree of parallelization te: becomes ineffective when job number > max_nr_parallel_jobs which is set in MATRIX_configuration file	
# sw ⁺ # sw ⁺ # sw ⁺ # sw # cru # cru # not	<pre>itch to turn on (1) and off (0) distributions itch to save previous result of this run (in result/"run"/saved_result_\$i) itch to save previous log of this run (in log/"run"/saved_result_\$i)). witch to (0) only include main run in results; (1) also all extrapolation (pr ucial to set to 0 if re-running main with different inputs (apart from precis te: if missing (default) pre runs used if important for precision</pre>	•
# # sw # spe	itch to keep full job output (0), reduce (1) or minimize (2) workload on slov ecify integer value (grid-/pre-run reproducible)	
Bot (108	8,0) Git-release_candidate (Fundamental Fld) 9:56AM 4.63	

- After changing into the run directory we start the run script
- \$./bin/run_process
- First, choose a name for the run:

|===>> run_my_first_ZZ

- The MATRIX run shell has many options, eg, modify input files typing:
- ===>> parameter

|===>> model

[[wiesemann:~/different-branch-munich/MATRIX/run/ppeeexex04_MATRIX] ./bin/run_process /-----MATRIX: A fully-differential NNLO(+NNLL) process library \\ // / \ / _ \ \/ || | |_| | \\ // // \\ $|| \rangle \rangle$ 11 \\ // \\ Version: 1.0.0.release_candidate4 Aug 2017 Munich -- the MUlti-chaNnel Integrator at swiss (CH) precision --Automates qT-subtraction and Resummation to Integrate X-sections)==== +)==== +)==== + |)==== + |-)==== M. Grazzini (grazzini@physik.uzh.ch) S. Kallweit (stefan.kallweit@cern.ch) M. Wiesemann (marius.wiesemann@cern.ch) MATRIX is based on a number of different computations and tools from various people and groups. Please acknowledge their efforts by citing the list of references which is created with every run. ----------------/ <<MATRIX-READ>> Type name of folder for this run (has to start with "run_"). "ENTER" to create and use "run_01". Press TAB or type "list" to show existing runs. Type "exit" or "quit" to stop. Any other folder will be created. ==========>> run_my_first_ZZ <<MATRIX-READ>> Type one of the following commands: ("TAB" for auto-completion) General commands description help >> Show help menu. help <command> >> Show help message for specific <command>. list >> List available commands again. exit >> Stop the code. quit Stop the code. >> Input to modify description _____ >> Modify "parameter.dat" input file in editor. parameter >> Modify "model.dat" input file in editor. model >> Modify "distribution.dat" input file in editor. distribution Run-mode to start description >> Start cross section computation in standard mode. run_grid >> Start only grid setup phase. >> Start only extrapolation (grid must be already done). run_pre run_pre_and_main >> Start after grid setup (grid must be already done). >> Start only main run (other runs must be already done). run main run_results >> Start only result combination. run_gnuplot Start only gnuplotting the results. >> setup_run >> Setup the run folder, but not start running. Remove run folder (including input/log/result). delete_run >> tar_run Create <run_folder>.tar (including input/log/result). >> =========>> parameter l=======>> model

- After changing into the r we start the run script
- \$./bin/run_proces
- First, choose a name for
 |==>> run_my_firs
- The MATRIX run shell l options, eg, modify input
- ===>> parameter
- |===>> model

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masses
#/ Block MASS
1 0.000000 # M_d
2 0.000000 # M_u
3 0.000000 # M_s
5 0.000000 # M b
6 1.732000e+02 # M_t
11 0.000000 # M_e
12 0.000000 # M_Ve
14 0.000000 # M_vm
15 1.777000e+00 # M_tau
$16 0.000000 \# M_Vt$ 23 9.118760e+01 # M 7
24 8.038500e+01 # M_W
25 1.250000e+02 # M_H
#
inputs for the SM
#/
Block SMINPUTS
2 1.100390e-05 # G_F
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Yukawa couplings
#Block YUKAWA
5 4.750000e+00 # M_YB
6 1.730000e+02 # M_YT
15 1.77700000+00 # M_TIAU
#\
decays widths
#/ DFCAY 6 1.442620e+00 # WT
DECAY 23 2.495200e+00 # WZ
DECAY 24 2.085400e+00 # WW
DECAY 25 4.070000e-03 # WH
-UU-:F1 model.dat
Folding buffer done



How to run # MATRIX d

- After changing into the we start the run script
- \$./bin/run_proces
- First, choose a name for
 |==>> run_my_firs
- The MATRIX run shell options, eg, modify input
 - ===>> parameter
- ===>> model
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- After changing into the run directory we start the run script
- \$./bin/run_process
- First, choose a name for the run:

|===>> run_my_first_ZZ

- The MATRIX run shell has many options, eg, modify input files typing:
- |===>> parameter
- |===>> model
- |===>> distribution
- Now we can start the run, type

|===>> run

```
[[wiesemann:~/different-branch-munich/MATRIX/run/ppeeexex04_MATRIX] ./bin/run_process
          /-----
           MATRIX: A fully-differential NNLO(+NNLL) process library
                                                       \\ //
                      \/ ||
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                   Version: 1.0.0.release_candidate4
                                                      Aug 2017
           Munich -- the MUlti-chaNnel Integrator at swiss (CH) precision --
           Automates qT-subtraction and Resummation to Integrate X-sections
             )==== + )==== + )==== + |)==== + |-)====
           M. Grazzini
                                                (grazzini@physik.uzh.ch)
           S. Kallweit
                                               (stefan.kallweit@cern.ch)
           M. Wiesemann
                                               (marius.wiesemann@cern.ch)
           MATRIX is based on a number of different computations and tools
           from various people and groups. Please acknowledge their efforts
           by citing the list of references which is created with every run.
<<MATRIX-READ>> Type name of folder for this run (has to start with "run_").
              "ENTER" to create and use "run_01". Press TAB or type "list" to
              show existing runs. Type "exit" or "quit" to stop. Any other
              folder will be created.
 ==========>> run_my_first_ZZ
<<MATRIX-READ>> Type one of the following commands: ("TAB" for auto-completion)
                               General commands
                      description
help
                  >> Show help menu.
help <command>
                  >> Show help message for specific <command>.
                 >> List available commands again.
list
exit
                     Stop the code.
                  >>
quit
                      Stop the code.
                  >>
 Input to modify
                      description
                  >> Modify "parameter.dat" input file in editor.
parameter
                  >> Modify "model.dat" input file in editor.
model
                      Modify "distribution.dat" input file in editor.
distribution
                  >>
Run-mode to start
                      description
                             >> Start cross section computation in standard mode.
run
run_grid
                      Start only grid setup phase.
                  >>
                  >> Start only extrapolation (grid must be already done).
run_pre
run_pre_and_main
                 >> Start after grid setup (grid must be already done).
                  >> Start only main run (other runs must be already done).
run main
run_results
                  >> Start only result combination.
run_gnuplot
                      Start only gnuplotting the results.
                  >>
setup_run
                  >> Setup the run folder, but not start running.
delete_run
                      Remove run folder (including input/log/result).
                  >>
tar_run
                      Create <run_folder>.tar (including input/log/result).
                  >>
l========>> parameter
 ========>> model
 ========>> distribution
 ========>> run
```

- After changing into the run directory we start the run script
- \$./bin/run_process
- First, choose a name for the run:

|===>> run_my_first_ZZ

- The MATRIX run shell has many options, eg, modify input files typing:
- |===>> parameter
- |===>> model
- |===>> distribution
- Now we can start the run, type

|===>> run

The code goes through all run phases and collects the results at the very end. With default inputs it runs LO with 1% accuracy.

<<MATRIX-JOBS>> | 2017-10-16 16:33:50 | Queued: 2 | Running: 0 | Finished: 0 <<MATRIX-JOBS>> | 2017-10-16 16:33:55 | Queued: 0 | Running: 2 | Finished: 0 <<MATRIX-JOBS>> | 2017-10-16 16:34:00 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2017-10-16 16:34:00 | Queued: 0 | Running: 0 | Finished: 2 | <MATRIX-INFO>> All runs successfully finished. <MATRIX-INFO>> Cleaning previous results (result run)... <MATRIX-INFO>> Collecting and combining results... <<MATRIX-JOBS>> | 2017-10-16 16:34:00 | Queued: 2 | Running: 0 | Finished: 0 <<MATRIX-JOBS>> | 2017-10-16 16:34:05 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2017-10-16 16:34:05 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2017-10-16 16:34:05 | Queued: 0 | Running: 0 | Finished: 2 | <MATRIX-INFO>> Plotting results with gnuplot... <MATRIX-INFO>> Trying to plot: pT_lep1_lep2__L0 <MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <MATRIX-INFO>> Trying to plot: pT_emZ1epZ2__L0 <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated. <MATRIX-INFO>> Trying to plot: pT_ep1__LO <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated <<MATRIX-INFO>> Trying to plot: pT_lep1__L0 <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated <MATRIX-INFO>> Trying to plot: m_lep1_lep2__L0 <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated. <MATRIX-INFO>> Trying to plot: dR_em1_ep1__LO <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated. <MATRIX-INFO>> Trying to plot: pT_lep2__L0 <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated. <MATRIX-INFO>> Trying to plot: pT_em1__LO <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated. <MATRIX-INFO>> Trying to plot: n_jets__LO <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated <<MATRIX-INFO>> Trying to plot: m_Z1__L0 <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated <MATRIX-INFO>> Trying to plot: pT_emZ2epZ1__L0 ATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated <MATRIX-INFO>> Trying to plot: m_Z2__L0 <MATRIX-INFO>> Running gnuplot... <MATRIX-INFO>> Plot successfully generated. <MATRIX-INFO>> Combining all pdf files into single file "all_plots.pdf"... Final result for: p p --> e^- e^- e^+ e^+ @ 13 TeV LHC <MATRIX-RESULT> 1 separate run was made #----\ # LO-run #----/ <MATRIX-RESULT> PDF: NNPDF30_lo_as_0118 <<u>MATRIX-RESULT> Total rate (possibly within cuts):</u> <MATRIX-RESULT> LO: 5.815 fb +/- 0.027 fb (muR, muF unc.: +6.3% -7.4%) <MATRIX-RESULT> All results (including the distributions) can be found in: <MATRIX-RESULT> /home/wiesemann/different-branch-munich/MATRIX/run/ppeeexex04_MATRIX/resul [wiesemann:~/different-branch-munich/MATRIX/run/ppeeexex04_MATRIX]

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- starts result combination+gnuplot
- prints final result at the end

2017-10-16 16:33:50 | Queued: 2 | Running: 0 | Finished: 0 <MATRIX-JOBS>> | <MATRIX-JOBS>> | 2017-10-16 16:33:55 | Queued: 0 | Running: 2 | Finished: 0 <MATRIX-JOBS>> | 2017-10-16 16:34:00 | Queued: 0 | Running: 0 | Finished: 2 <MATRIX-JOBS>> | 2017-10-16 16:34:00 | Queued: 0 | Running: 0 | Finished: 2 All runs successfully finished. aning previous results (result run)... ollecting and combining results... 2017-10-16 16:34:00 | Queued: 2 | Running: 0 | Finished: 0 <MATRIX-JOBS>> | 2017-10-16 16:34:05 | Queued: 0 | Running: 0 | Finished: 2 <MATRIX-JOBS>> | 2017-10-16 16:34:05 | Queued: 0 | Running: 0 | Finished: 2 <MATRIX-JOBS>> | 2017-10-16 16:34:05 | Queued: 0 | Running: 0 | Finished: 2 | -INFO>> Plotting results with gnuplot... <MATRIX-INFO>> Trying to plot: pT_lep1_lep2__LO INFO>> Running gnuplot... NFO>> Plot successfully generated. -INFO>> Trying to plot: pT_emZ1epZ2__LO -INFO>> Running gnuplot... NFO>> Plot successfully generated. NFO>> Trying to plot: pT_ep1__LO (MATRIX-INFO>> Running gnuplot... -INFO>> Plot successfully generated. -INFO>> Trying to plot: pT_lep1__LO -INFO>> Running gnuplot... MATRIX-INFO>> Plot successfully generated. NFO>> Trying to plot: m_lep1_lep2__LO [NFO>> Running gnuplot... -INFO>> Plot successfully generated. -INFO>> Trying to plot: dR_em1_ep1__LO [NFO>> Running gnuplot... VFO>> Plot successfully generated. MATRIX-INFO>> Trying to plot: pT_lep2__LO ·INFO>> Running gnuplot... O>> Plot successfully generated. 0>> Trying to plot: pT_em1 _LO 0>> Running gnuplot... D>> Plot successfully generated. -INFO>> Trying to plot: n_jets__LO MATRIX-INFO>> Running gnuplot... NFO>> Plot successfully generated. -INFO>> Trying to plot: m_Z1__LO NFO>> Running gnuplot... [NFO>> Plot successfully generated. INFO>> Trying to plot: pT_emZ2epZ1__L0 NFO>> Running gnuplot... NFO>> Plot successfully generated. MATRIX-INFO>> Trying to plot: m_Z2__L0 (-INFO>> Running gnuplot... (-INFO>> Plot successfully generated. <MATRIX-INFO>> Combining all pdf files into single file "all_plots.pdf"... Final result for: <MATRIX-RESULT> 1 separate run was made #----\ # L0-run | #----/ <MATRIX-RESULT> PDF: NNPDF30_lo_as_0118 <MATRIX-RESULT> Total rate (possibly within cuts): <MATRIX-RESULT> LO: 5.815 fb +/- 0.027 fb (muR, muF unc.: +6.3% -7.4%) <MATRIX-RESULT> All results (including the distributions) can be found in: <MATRIX-RESULT> /home/wiesemann/different-branch-munich/MATRIX/run/ppeeexex04_MATRIX/resul [wiesemann:~/different-branch-munich/MATRIX/run/ppeeexex04 MATRIX]
now go to the run folder we just created through compilation and let's start running

```
$ cd run/ppz01_MATRIX
```

task:	 start runing script & go through interactive shell: I. give it some name 2. check parameter.dat, model.dat, distribution.dat
hint:	the on-screen output tells you everything you need to know, e.g. set default editor either through export or MATRIX_configuration

🕐 🕒 🌒 💼 n	nars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0 — ssh bnd005@bnd01.iihe.ac.be — 107×4
< <matrix-make>></matrix-make>	result folder with every run. This compilation of MATRIX uses directly the code OpenLoops from http://openloops.hepforge.org by F. Buccioni, F. Cascioli, JN. Lang, J. Lindert, P. Maierhoefer, S. Pozzorini, H. Zhang, M. Zoller. You have to cite the relavant references in CITATIONS.bib, when using results obtained with this
< <matrix-make>> <<matrix-make>></matrix-make></matrix-make>	You have agreed with all MATRIX usage terms. Creating input files for process ppz01 inside folder /var/bnd/us ers/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/input_files/ppz01
< <matrix-make>> <<matrix-make>></matrix-make></matrix-make>	Starting compilation Using compiled LHAPDF installation under (config/MATRIX_configuration) path_to_lbapdf=/var/bpd/tbeo/LHAPDE-6.5.4/bin/lbapdf-config
< <matrix-make>></matrix-make>	Download and Compilation of OpenLoops via git clone -b public_beta https://gitlab.com/openloops/OpenLoops.git into /var /bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/OpenLoo ps-install
< <matrix-make>></matrix-make>	Downloading OpenLoops
< <matrix-make>> <<matrix-make>></matrix-make></matrix-make>	Compiling OpenLoops Extracting and Compiling Chaplin from /var/bnd/users/bnd005/Matr ix_tutorial/MATRIX_v2.1.0/external/chaplin-1.2.tar into /var/bnd /users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/chaplin- install
< <matrix-make>></matrix-make>	Extracting and Compiling Cln from /var/bnd/users/bnd005/Matrix_t utorial/MATRIX_v2.1.0/external/cln-1.3.4.tar into /var/bnd/users /bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/cln-install
< <matrix-make>></matrix-make>	Extracting and Compiling Ginac from /var/bnd/users/bnd005/Matrix _tutorial/MATRIX_v2.1.0/external/ginac-1.6.2.tar into /var/bnd/u sers/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/ginac- install
< <matrix-make>></matrix-make>	Compiling process <ppz01>, this may take a while (see make.log file to monitor the progress)</ppz01>
< <matrix-make>></matrix-make>	Downloading and compiling ppvj amplitude with OpenLoops
< <matrix-make>></matrix-make>	Downloading and compiling ppvj_ew amplitude with OpenLoops
< <matrix-make>></matrix-make>	Creating process folder in "run"-directory: "/var/bnd/users/bnd0 05/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX"
< <matrix-info>></matrix-info>	Process folder successfully created.
< <matrix-info>></matrix-info>	Process generation finished, to go to the run directory type:
	cd /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX
< <matrix-infu>></matrix-infu>	/bin/run process
[bnd005@bnd01 M/	ATRIX_v2.1.0]\$



 now go to the run folder we just created through compilation and let's start running
 \$ cd run/ppz01_MATRIX

🖲 😑 🍯 🔤 mars — bnd	1005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be -
< <matrix-make>></matrix-make>	This compilation of MATRIX uses directly the code OpenLoops from
	http://openloops.hepforge.org by F. Buccioni, F. Cascioli, JN.
	Lang, J. Lindert, P. Maierhoefer, S. Pozzorini, H. Zhang, M.
	Zoller. You have to cite the relavant references in
	CITATIONS.bib, when using results obtained with this
	installation.
< <matrix-make>></matrix-make>	You have agreed with all MATRIX usage terms.
< <matrix-make>></matrix-make>	Creating input files for process ppz01 inside folder /var/bnd/us
	ers/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/input_files/ppz01
< <matrix-make>></matrix-make>	Starting compilation
< <matrix-make>></matrix-make>	Using compiled LHAPDF installation under
	(config/MATRIX_configuration)
	path_to_lhapdf=/var/bnd/theo/LHAPDF-6.5.4/bin/lhapdf-config
< <matrix-make>></matrix-make>	Download and Compilation of OpenLoops via git clone -b
	public beta https://gitlab.com/openloops/OpenLoops.git into /var
	/bnd/users/bnd005/Matrix tutorial/MATRIX v2.1.0/external/OpenLoo
	ps-install
< <matrix-make>></matrix-make>	Downloading OpenLoops
< <matrix-make>></matrix-make>	Compiling OpenLoops
< <matrix-make>></matrix-make>	Extracting and Compiling Chaplin from /var/bnd/users/bnd005/Matr
	ix tutorial/MATRIX v2.1.0/external/chaplin-1.2.tar into /var/bnd
	/users/bnd005/Matrix tutorial/MATRIX v2.1.0/external/chaplin-
	install
< <matrix-make>></matrix-make>	Extracting and Compiling Cln from /var/bnd/users/bnd005/Matrix_t
	utorial/MATRIX v2.1.0/external/cln-1.3.4.tar into /var/bnd/users
	/bnd005/Matrix_tutorial/MATRIX_v2.1.0/external/cln-install
< <matrix-make>></matrix-make>	Extracting and Compiling Ginac from /var/bnd/users/bnd005/Matrix
	tutorial/MATRIX v2.1.0/external/ginac-1.6.2.tar into /var/bnd/u
	sers/bnd005/Matrix tutorial/MATRIX v2.1.0/external/ginac-
	install
< <matrix-make>></matrix-make>	Compiling process <ppz01>, this may take a while</ppz01>
	(see make.log file to monitor the progress)
< <matrix-make>></matrix-make>	Downloading and compiling ppvj amplitude with OpenLoops
< <matrix-make>></matrix-make>	Downloading and compiling ppvj ew amplitude with OpenLoops
< <matrix-make>></matrix-make>	Creating process folder in "run"-directory: "/var/bnd/users/bnd0
	05/Matrix tutorial/MATRIX v2.1.0/run/ppz01 MATRIX"
< <matrix-info>></matrix-info>	Process folder successfully created.
< <matrix-info>></matrix-info>	Process generation finished, to go to the run directory type:
	cd /var/bnd/users/bnd005/Matrix tutorial/MATRIX v2.1.0/run/ppz01 MATRIX
< <matrix-info>></matrix-info>	and start run by typing:
	./bin/run process
[bnd0050bnd01 MA	TRIX v2.1.0]\$ cd /var/bnd/users/bnd005/Matrix tutorial/MATRIX v2.1.0/run/ppz01
[bnd0050bnd01 pr	pz01 MATRIX1\$





- now go to the run folder we just created through compilation and let's start running
 - \$ cd run/ppz01_MATRIX
 - \$./bin/run_process

=======>>

📀 🕒 🍺 🔤 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44

[[bnd005@bnd01 ppz01_MATRIX]\$./bin/run_process



<<MATRIX-READ>> Type name of folder for this run (has to start with "run_"). "ENTER" to create and use "run_01". Press TAB or type "list" to show existing runs. Type "exit" or "quit" to stop. Any other folder will be created.



75

- now go to the run folder we just created through compilation and let's start running
 - \$ cd run/ppz01_MATRIX
 - \$./bin/run_process
 - > run_Z_onshell_LO (choose name)

📀 🕒 🍺 🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44

[[bnd005@bnd01 ppz01_MATRIX]\$./bin/run_process



<<MATRIX-READ>> Type name of folder for this run (has to start with "run_"). "ENTER" to create and use "run_01". Press TAB or type "list" to show existing runs. Type "exit" or "quit" to stop. Any other folder will be created. []========>> run_Z_onshell_LO



- now go to the run folder we just created through compilation and let's start running
 - \$ cd run/ppz01_MATRIX
 - \$./bin/run_process
 - > run_Z_onshell_LO (choose name)

💿 😑 📄 🛅 mars — bnd005@	@bnd01:/va	nr/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.a
M. Gra S. Kal M. Wie 	zzini lweit semann	(grazzini@physik.uzh.ch) (stefan.kallweit@cern.ch) (marius.wiesemann@cern.ch)
MATRIX from v by cit \	is bas arious ing the	ed on a number of different computations and tools people and groups. Please acknowledge their efforts references in CITATIONS.bib created with every run.
< <matrix-read>> Typ "EN sho fol</matrix-read>	e name TER" to w exist der wil	of folder for this run (has to start with "run_"). create and use "run_01". Press TAB or type "list" to ing runs. Type "exit" or "quit" to stop. Any other l be created.
< <matrix-read>> Typ</matrix-read>	e one o	f the following commands: ("TAB" for auto-completion)
General commands	d	escription
help help <command/> list exit quit	>> S >> S >> L >> S >> S	how help menu. how help message for specific <command/> . ist available commands again. top the code.
Input to modify	d	escription
parameter model distribution dddistribution	>> M >> M >> M >> M >> M	lodify "parameter.dat" input file in editor. lodify "model.dat" input file in editor. lodify "distribution.dat" input file in editor. lodify "dddistribution.dat" input file in editor.
Run-mode to start	d	escription
run run_grid run_pre run_pre_and_main run_main run_results run_gnuplot setup_run delete_run	>> S >> S >> S >> S >> S >> S >> S >> S	tart cross section computation in standard mode. tart only grid setup phase. tart only extrapolation (grid must be already done). tart after grid setup (grid must be already done). tart only main run (other runs must be already done). tart only result combination. tart only gnuplotting the results. terup the run folder, but not start running. temove run folder (including input/log/result).
=====>>		reate run_roiderz.tar (including input/iog/result).



- now go to the run folder we just created through compilation and let's start running
 - \$ cd run/ppz01_MATRIX
 - \$./bin/run_process
 - > run_Z_onshell_LO (choose name)
 - > parameter/model/distribution

🦲 😑 📄 mars — bnd0050	@bnd01:	:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@br	ıd01.iihe.ac.be ·
 MATRIX from v by cit \	(is b variou ing t	based on a number of different computations and tools Is people and groups. Please acknowledge their efforts The references in CITATIONS.bib created with every run.	
< <matrix-read>> Typ "EN sho fol =====>> run <<matrix-read>> Typ</matrix-read></matrix-read>	oe nam ITER" ow exi .der w i_Z_on oe one	ne of folder for this run (has to start with "run_"). to create and use "run_02". Press TAB or type "list" to sting runs. Type "exit" or "quit" to stop. Any other will be created. wishell_LO e of the following commands: ("TAB" for auto-completion)	
General commands		description	
help help <command/> list exit quit	>> >> >> >> >> >>	Show help menu. Show help message for specific <command/> . List available commands again. Stop the code. Stop the code.	
Input to modify		description	
parameter model distribution dddistribution	>> >> >> >>	Modify "parameter.dat" input file in editor. Modify "model.dat" input file in editor. Modify "distribution.dat" input file in editor. Modify "dddistribution.dat" input file in editor.	
Run-mode to start		description	
run run_grid run_pre run_pre_and_main	>> >> >> >>	Start cross section computation in standard mode. Start only grid setup phase. Start only extrapolation (grid must be already done). Start after grid setup (grid must be already done).	
run_main run_results run_gnuplot	>> >> >>	Start only main run (other runs must be already done). Start only result combination. Start only gnuplotting the results.	
setup_run delete_run tar_run ===========>> par	>> >> >> amete	Setup the run folder, but not start running. Remove run folder (including input/log/result). Create <run_folder>.tar (including input/log/result). er</run_folder>	
====>> mod =======>> dis ======>>	lel tribu	ition	





- now go to the run folder we just created through compilation and let's start running
 - \$ cd run/ppz01_MATRIX
 - \$./bin/run_process
 - > run_Z_onshell_LO (choose name)
 - > parameter/model/distribution
 - > run

📀 😑 🥃 📷 mars — bnd005@	bnd01:	/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.b	be ·
 MATRIX from va by cit: \	is b ariou ing t	ased on a number of different computations and tools s people and groups. Please acknowledge their efforts he references in CITATIONS.bib created with every run. /	
< <matrix-read>> Type "EN" show fold =====>> run</matrix-read>	e nam TER" w exi der w _Z_on	e of folder for this run (has to start with "run_"). to create and use "run_02". Press TAB or type "list" to sting runs. Type "exit" or "quit" to stop. Any other ill be created. shell_LO	
< <mairix-read>> lyp</mairix-read>	e one	of the following commands: ("TAB" for auto-completion)	
General commands		description	
 help help <command/> list exit	>> >> >> >>	Show help menu. Show help message for specific <command/> . List available commands again. Stop the code.	
quit	>>	Stop the code.	
Input to modify		 description 	
parameter model distribution dddistribution	>> >> >> >>	Modify "parameter.dat" input file in editor. Modify "model.dat" input file in editor. Modify "distribution.dat" input file in editor. Modify "dddistribution.dat" input file in editor.	
Run-mode to start		description	
 run		Start cross section computation in standard mode.	
run_grid	>>	Start only grid setup phase.	
run_pre	>>	Start only extrapolation (grid must be already done).	
run_pre_and_main	>>	Start after grid setup (grid must be already done).	
run_main	>>	Start only main run (other runs must be already done).	
run_results	>>	Start only result combination.	
run_gnuplot	>>	Start only gnuplotting the results.	
setup_run	>>	Setup the run folder, but not start running.	
delete_run	>>	Remove run folder (including input/log/result).	
tar_run	>>	Create <run_folder>.tar (including input/log/result).</run_folder>	
=====>> para	amete	r	
=====>> mod	el		
====>> dis	tribu	tion	
======>> run			



- now go to the run folder we just created through compilation and let's start running
 - \$ cd run/ppz01_MATRIX
 - \$./bin/run_process
 - > run_Z_onshell_LO (choose name)
 - > parameter/model/distribution
 - > run

warmup: generation of integration grids

💿 😑 🔵 📷 mars — bnd0	05@bnd01:/	/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.a
help <command/>	>>	Show help message for specific <command/> .
list	>>	List available commands again.
exit	>>	Stop the code.
quit 	>>	Stop the code.
Input to modify		description
parameter	>>	Modify "parameter.dat" input file in editor.
model	>>	Modify "model.dat" input file in editor.
distribution	>>	Modify "distribution.dat" input file in editor.
dddistribution	>>	Modify "dddistribution.dat" input file in editor.
Run-mode to start		description
run	>>	Start cross section computation in standard mode.
run_grid	>>	Start only grid setup phase.
run_pre	>>	Start only extrapolation (grid must be already done).
run_pre_and_main	>>	Start after grid setup (grid must be already done).
run_main	>>	Start only main run (other runs must be already done).
run_results	>>	Start only result combination.
run_gnuplot	>>	Start only gnuplotting the results.
setup_run	>>	Setup the run folder, but not start running.
delete_run	>>	Remove run folder (including input/log/result).
tar_run	>>	Create <run_folder>.tar (including input/log/result).</run_folder>
=====>> p	arameter	
=====>> m	odel	
=====>> d	istribu	tion
=====>> r	un	
< <matrix-info>> N</matrix-info>	ew Run	folder created: /var/bnd/users/bnd005/Matrix_tutorial/MA
Т	RIX_v2.2	1.0/run/ppz01_MATRIX/run_Z_onshell_LO.
< <matrix-info>> U</matrix-info>	sing LH/	APDF version 6.5.4
< <matrix-info>> F</matrix-info>	ound exp	ported variable \$LHAPDF_DATA_PATH with colon-separated
1	ist: /c	vmfs/sft.cern.ch/lcg/external/lhapdfsets/current/:/cvmfs
/	sft.cern	n.ch/lcg/releases/MCGenerators/lhapdf/6.5.1-389ee/x86_64
—	centos7-	-gcc11-opt/share/LHAPDF:. Usinig first entry
/	cvmfs/s	ft.cern.ch/lcg/external/lhapdfsets/current/ as folder
f	or down	load.
< <matrix-info>> A</matrix-info>	11 PDF 9	sets already installed. Continuning without download
< <matrix-info>> N</matrix-info>	ow it's	time for running
< <matrix-info>> R</matrix-info>	unning :	in multicore mode
< <matrix-info>> S</matrix-info>	tarting	grid setup (warmup)
< <matrix-jobs>> </matrix-jobs>	2024-08	3-24 22:39:36 Queued: 3 Running: 0 Finished: 0
< <matrix-jobs>> </matrix-jobs>	2024-08	3-24 22:39:41 Queued: 0 Running: 3 Finished: 0





- now go to the run folder we just created through compilation and let's start running
 - \$ cd run/ppz01_MATRIX
 - \$./bin/run_process
 - > run_Z_onshell_LO (choose name)
 - > parameter/model/distribution
 - > run

warmup: generation of integration grids

pre-run: estimate of runtime (short runs)

🧕 😑 🛑 🛅 mars — bnd	1005@bnd01:	/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be
parameter	>>	Modify "parameter.dat" input file in editor.
model	>>	Modify "model.dat" input file in editor.
distribution	>>	Modify "distribution.dat" input file in editor.
dddistribution	>>	Modify "dddistribution.dat" input file in editor.
Run-mode to star	t	description
run	>>	Start cross section computation in standard mode.
run_grid	>>	Start only grid setup phase.
run_pre	>>	Start only extrapolation (grid must be already done).
<pre>run_pre_and_main</pre>	ı >>	Start after grid setup (grid must be already done).
run_main	>>	Start only main run (other runs must be already done).
run_results	>>	Start only result combination.
run_gnuplot	>>	Start only gnuplotting the results.
setup_run	>>	Setup the run folder, but not start running.
delete_run	>>	Remove run folder (including input/log/result).
tar_run	>>	Create <run_folder>.tar (including input/log/result).</run_folder>
[=====>>	paramete	r
[======>>	model	
[======>>	distribu	tion
[=====>>	run	
< <matrix-info>></matrix-info>	New Run	folder created: /var/bnd/users/bnd005/Matrix_tutorial/MA
	TRIX_v2.	1.0/run/ppz01_MATRIX/run_01.
< <matrix-info>></matrix-info>	Using LH	APDF version 6.5.4
< <matrix-info>></matrix-info>	Found ex	ported variable \$LHAPDF_DATA_PATH with colon-separated
	list: /c	vmfs/sft.cern.ch/lcg/external/lhapdfsets/current/:/cvmfs
	/sft.cer	n.ch/lcg/releases/MCGenerators/lhapdf/6.5.1-389ee/x86_64
	-centos7	-gcc11-opt/share/LHAPDF:. Usinig first entry
	/cvmfs/s	ft.cern.ch/lcg/external/lhapdfsets/current/ as folder
	for down	load.
< <matrix-info>></matrix-info>	ALL PDF	sets already installed. Continuning without download
< <matrix-info>></matrix-info>	Now it's	time for running
< <matrix-info>></matrix-info>	Running	in multicore mode
< <mairix-info>></mairix-info>	Starting	grid setup (warmup)
< <mairix-jobs>></mairix-jobs>	2024-0	8-24 22:32:28 Queued: 3 Running: 0 Finished: 0
< <mairix-jobs>></mairix-jobs>	2024-0	8-24 22:32:33 Queued: 0 Running: 3 Finished: 0
< <mairix-jobs>></mairix-jobs>	2024-0	8-24 22:35:58 Queued: 0 Running: 2 Finished: 1
< <mairix-jobs>></mairix-jobs>	2024-0	8-24 22:36:03 Queued: 0 Running: 0 Finished: 3
< <mairix-jobs>></mairix-jobs>	2024-0	8-24 22:36:03 Queued: 0 Running: 0 Finished: 3
< <mairix-info>></mairix-info>	All runs	successfully finished.
< <mairix-info>></mairix-info>	Starting	runs to determine runtimes (pre run)
< <mairix-jobs>></mairix-jobs>	2024-0	8-24 22:36:03 Queued: 3 Running: 0 Finished: 0
< <mairix-jobs>></mairix-jobs>	2024-0	8-24 22:36:08 Queued: 0 Running: 3 Finished: 0



- through compilation and let's start running

 - ./bin/run process

 - run

warmup: generation of integration grids

🕒 🌑 🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44 now go to the run folder we just created for download. <<MATRIX-INFO>> All PDF sets already installed. Continuning without download... <<MATRIX-INFO>> Now it's time for running... <<MATRIX-INFO>> Running in multicore mode... <<MATRIX-INFO>> Starting grid setup (warmup)... <<MATRIX-JOBS>> | 2024-08-24 22:32:28 | Queued: 3 | Running: 0 | Finished: 0 cd run/ppz01 MATRIX \$ <<MATRIX-JOBS>> | 2024-08-24 22:32:33 | Queued: 0 | Running: 3 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 22:35:58 | Queued: 0 | Running: 2 | Finished: 1 <<MATRIX-JOBS>> | 2024-08-24 22:36:03 | Queued: 0 | Running: 0 | Finished: 3 \$ <<MATRIX-JOBS>> | 2024-08-24 22:36:03 | Queued: 0 | Running: 0 | Finished: 3 | <MATRIX-INFO>> All runs successfully finished. <MATRIX-INFO>> Starting runs to determine runtimes (pre run)... <<MATRIX-JOBS>> | 2024-08-24 22:36:03 | Queued: 3 | Running: 0 | Finished: 0 run Z onshell LO (choose name) <<MATRIX-JOBS>> | 2024-08-24 22:36:08 | Queued: 0 | Running: 3 | Finished: 0 2024-08-24 22:36:23 Queued: 0 | Running: 1 | Finished: 2 <<MATRIX-JOBS>> | <<MATRIX-JOBS>> | 2024-08-24 22:36:28 | Queued: 0 | Running: 0 | Finished: 3 > parameter/model/distribution <<MATRIX-JOBS>> | 2024-08-24 22:36:28 | Queued: 0 | Running: 0 | Finished: 3 <<MATRIX-INFO>> All runs successfully finished. <MATRIX-INFO>> Extrapolating runtimes... <<MATRIX-JOBS>> | 2024-08-24 22:36:28 | Queued: 1 | Running: 0 | Finished: 0 > <<MATRIX-JOBS>> | Queued: 0 | Running: 0 | Finished: 1 2024-08-24 22:36:33 <<MATRIX-JOBS>> | 2024-08-24 22:36:33 | Queued: 0 | Running: 0 | Finished: 1 <<MATRIX-JOBS>> | 2024–08–24 22:36:33 | Queued: 0 | Running: 0 | Finished: 1 | Pre-run result for: p p --> Z @ 13 TeV LHC **pre-run:** estimate of runtime (short runs) <MATRIX-RESULT> PDF: NNPDF31_nlo_as_0118_luxged <MATRIX-RESULT> Total rate (possibly within cuts): <MATRIX-RESULT> <MATRIX-RESULT> L0:4.911e+07 fb +/- 1.8e+05 fb (muR, muF unc.: +11.4% -12.4%) **main-run:** computation of cross sections <MATRIX-RESULT> -----MATRIX-RESULT> This result is very inaccurate and only a rough estimate! <MATRIX-RESULT> Wait until the main run finishes to get the final result! <<MATRIX-INFO>> Starting cross section computation (main run)... <<MATRIX-JOBS>> | 2024-08-24 22:36:33 | Queued: 3 | Running: 0 | Finished: 0 | <<MATRIX-JOBS>> | 2024-08-24 22:36:38 | Queued: 0 | Running: 3 | Finished: 0 |





- now go to the run folder we just created through compilation and let's start running
 - cd run/ppz01 MATRIX \$
 - ./bin/run process \$
 - run Z onshell LO (choose name)
 - > parameter/model/distribution
 - run >

warmup: generation of integration grids

pre-run: estimate of runtime (short runs)

LO-run <MATRIX-RESULT> PDF: NNPDF31_nlo_as_0118_luxged **main-run:** computation of cross sections <MATRIX-RESULT> Total rate (possibly within cuts): <MATRIX-RESULT> L0:4.912e+07 fb +/- 1.3e+05 fb (muR, muF unc.: +11.4% -12.5%) <MATRIX-RESULT> <MATRIX-RESULT> All results (including the distributions) can be found in: <MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_L0

final result: $\sigma(pp \to Z) = 49.1(1)^{+11.4\%}_{-12.5\%}$ nb

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 108×44 <<MATRIX-JOBS>> | 2024-08-24 22:43:41 | Queued: 3 | Running: 0 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 22:43:46 Queued: 0 | Running: 3 | Finished: 0 <<MATRIX-JOBS>> | Queued: 0 Running: 2 | Finished: 1 2024-08-24 22:44:01 Queued: 0 | Running: 0 | Finished: 3 <<MATRIX-JOBS>> | 2024-08-24 22:44:06 <<MATRIX-JOBS>> | 2024-08-24 22:44:06 | Queued: 0 | Running: 0 | Finished: 3 <MATRIX-INFO>> All runs successfully finished. <<MATRIX-INFO>> Cleaning previous results (result run)... <<MATRIX-INFO>> Collecting and combining results... <<MATRIX-JOBS>> | 2024-08-24 22:44:06 | Queued: 2 | Running: 0 | Finished: 0 2024-08-24 22:44:11 | Queued: 0 <MATRIX-JOBS>> | Running: 0 | Finished: 2 <<u>MATRIX-JOBS>> | 2024-08-24 22:44:11 | Queued: 0 |</u> Running: 0 | Finished: 2 <<MATRIX–JOBS>> | 2024–08–24 22:44:11 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-INFO>> Plotting results with gnuplot... <<MATRIX-INFO>> Trying to plot: y_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: n_jets__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: pT_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Combining all pdf files into single file "all_plots.pdf"...

> Final result for: рр—->Z

<MATRIX-RESULT> 1 separate run was made

[bnd005@bnd01 ppz01_MATRIX]\$

QCD and Monte Carlo event generators (Lecture 2 — hands-on session)







- now go to the run folder we just created through compilation and let's start running
 - \$ cd run/ppz01 MATRIX
 - ./bin/run process \$
 - > run Z onshell LO (choose name)

pre-run: estimate of runtime (short runs)

main-run: computation of cross sections nlo as 0118 luxged <MATRIX-RESULT> Total rate (possibly within cuts): <MATRIX-RESULT> L0:4.912e+07 fb +/- 1.3e+05 fb (muR, muF unc.: +11.4% -12.5%) <MATRIX-RESULT> <MATRIX-RESULT> All results (including the distributions) can be found in: <MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_L0 [bnd005@bnd01 ppz01_MATRIX]\$

final result: $\sigma(pp \to Z) = 49.1(1)^{+11.4\%}_{-12.5\%}$ nb

📀 😑 💼 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ad	c.be —
< <matrix-jobs>> 2024-08-24 22:43:41 Queued: 3 Running: 0 Finished: 0 <<matrix-jobs>> 2024-08-24 22:43:46 Queued: 0 Running: 3 Finished: 0 <<matrix-jobs>> 2024-08-24 22:44:01 Queued: 0 Running: 2 Finished: 1 <<matrix-jobs>> 2024-08-24 22:44:06 Queued: 0 Running: 0 Finished: 3 <<matrix-jobs>> 2024-08-24 22:44:06 Queued: 0 Running: 0 Finished: 3 <<matrix-jobs>> 2024-08-24 22:44:06 Queued: 0 Running: 0 Finished: 3 <<matrix-info>> All runs successfully finished. <<matrix-info>> Cleaning previous results (result run)</matrix-info></matrix-info></matrix-jobs></matrix-jobs></matrix-jobs></matrix-jobs></matrix-jobs></matrix-jobs>	
< <matrix-info>> Collecting and combining results <<matrix-jobs>> 2024-08-24 22:44:06 Queued: 2 Running: 0 Finished: 0 <<matrix-jobs>> 2024-08-24 22:44:11 Queued: 0 Running: 0 Finished: 2 <<matrix-jobs>> 2024-08-24 22:44:11 Queued: 0 Running: 0 Finished: 2 <<matrix-jobs>> 2024-08-24 22:44:11 Queued: 0 Running: 0 Finished: 2 <<matrix-info>> Plotting results with gnuplot <<matrix-info>> Trying to plot: y_Z_LO <<matrix-info>> Running gnuplot <<matrix-info>> Plot successfully generated.</matrix-info></matrix-info></matrix-info></matrix-info></matrix-jobs></matrix-jobs></matrix-jobs></matrix-jobs></matrix-info>	

Again you have a solution to this task in form of a bash file that you can just execute (inside the MATRIX v2.1.0/run/ppz01 MATRIX folder) from here: /var/bnd/theo/help/solution-2-running.sh

<MATRIX-RESULT> 1 separate run was made

QCD and Monte Carlo event generators (Lecture 2 — hands-on session)

September 6, 2024





Iet's checkout the run and the results we just created

task: investigate folder structure; go to result folder, find summary on-screen output, find used inputs, find integrated cross section (rates), find distributions, ...

question: look at Z p⊤ spectrum; why does it look so weird? (only first bin filled)

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LO — ssh bnd005@bnd01.iihe.a. <<MATRIX-JOBS>> | 2024-08-24 22:44:01 | Queued: 0 | Running: 2 | Finished: 1 | <<MATRIX-JOBS>> | 2024-08-24 22:44:06 | Queued: 0 | Running: 0 | Finished: 3 | <<MATRIX-JOBS>> | 2024-08-24 22:44:06 | Queued: 0 | Running: 0 | Finished: 3 | <MATRIX-INFO>> All runs successfully finished. <<MATRIX-INFO>> Cleaning previous results (result run)... <<MATRIX-INFO>> Collecting and combining results... <<MATRIX-JOBS>> | 2024-08-24 22:44:06 | Queued: 2 | Running: 0 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 22:44:11 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2024-08-24 22:44:11 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX–JOBS>> | 2024–08–24 22:44:11 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-INFO>> Plotting results with gnuplot... <<MATRIX-INFO>> Trying to plot: y_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: n_jets__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: pT_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Combining all pdf files into single file "all_plots.pdf"...



<MATRIX-RESULT> 1 separate run was made





		🖲 😑 🔵 🛅 mars	— bnd005@bnd01:	:/var/bnd/users/bnd005/M	atrix_tutorial/MATRIX	(_v2.1.0/run/ppz01_MA	TRIX/result/run_Z_ons	hell_LO/LO-run/distribu	itionsLO — ssh bnd(05@bnd01.iihe.ac.	be — 152×25
		File Edit Opt	ions Buffers 1	Tools Help							
		# left-edge	right-edge	scale-central	central-error	scale-min	min-error	scale-max	max-error	rel-down	rel-up
		0	5	5726920.0	5427.42	5180883.7	4900.48	6203723.7	5892.52	-9.53%	8.33%
		5	10	0	0	0	0	0	0	0%	0%
		10	15	0	0	0	0	0	0	0%	0%
BVB		15	20	0	0	0	0	0	0	0%	0%
09		20	25	0	0	0	0	0	0	0%	0%
	inc	25	30	0	0	0	0	0	0	0%	0%
	jus	30	35	0	0	0	0	0	0	0%	0%
г		35	40	0	0	0	0	0	0	0%	0%
		40	45	0	0	0	0	0	0	0%	0%
	ta	45	50	0	0	0	0	0	0	0%	0%
		50	55	0	0	Ø	0	Ø	0	0%	0%
		55	00 45	0	0	0	0	0	0	Ø%	0%
		00 65	00 70	0	0	0	0	0	0	0%	Ø%
		70	76	0	0	0	0	0	0	0%	0%
		76	80	0	0	0	0	0	0	0% 0%	0%
		80	85	0	0	0	0	0	0	0% 0%	0%
		85	90	0	0	0	0	0	0	0%	0%
		90	95	0	0	0	0	0	0	0%	0%
		95	100	0	0	0	0	0	0	0%	0%
		100	105	0	0	0	0	0	0	0%	0%
		-UU-:F1	pT_ZLO.dat	Top L1 (Funda	mental)						
		For informati	on about GNU E	Emacs and the GNU s	ystem, type C-h	C-a.					
		_						Final re	sult for:	Î	
		. •		. —				p p> Z	@ 13 TeV LHC		
	question: look at ∠ p⊤ spectrum; why does it look so weird?						(/	
							-RESULT> 1 separate	e run was made			
							#\				
							#\ # LO_run				
							#/				
						<matrix <matrix< td=""><td>-RESULT> PDF: NNPDF -RESULT> Total_rate</td><td>31_nlo_as_0118_luxq (possibly within c</td><td>ed uts):</td><td></td><td></td></matrix<></matrix 	-RESULT> PDF: NNPDF -RESULT> Total_rate	31_nlo_as_0118_luxq (possibly within c	ed uts):		

```
<MATRIX-RESULT> L0:4.912e+07 fb +/- 1.3e+05 fb (muR, muF unc.: +11.4% -12.5%)
 <MATRIX-RESULT> ------
<MATRIX-RESULT> All results (including the distributions) can be found in:
<MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_L
[bnd005@bnd01 ppz01_MATRIX]$ cd result/run_Z_onshell_LO/
[bnd005@bnd01 run_Z_onshell_LO]$
```

QCD and Monte Carlo event generators (Lecture 2 – hands-on session)





many additional command-line options, use "-h" to show all options

./matrix -h

	🛅 MATRIX — -bash — 86×44
[[mars:~/Uni/Own_Codes/p usage: matrix [-h] [c] [folder [old_gin [<process:< td=""><td>ublish_MATRIX_v2.1.0/MATRIX] ./matrix -h Lean_process] [install_openloops] [agree_to_all] _name_extension FOLDER_NAME_EXTENSION] [no_compile] hac] [new_ginac] >]</td></process:<>	ublish_MATRIX_v2.1.0/MATRIX] ./matrix -h Lean_process] [install_openloops] [agree_to_all] _name_extension FOLDER_NAME_EXTENSION] [no_compile] hac] [new_ginac] >]
MATRIX.	
positional arguments: <process></process>	<pre>process name, choose from list ['pph21', 'ppz01', 'ppw01', 'ppwx01', 'ppeex02', 'ppnenex02', 'ppenex02', 'ppexne02', 'ppaa02', 'ppeexa03', 'ppnenexa03', 'ppenexa03', 'ppexnea03', 'ppzz02', 'ppwxw02', 'ppemexmx04', 'ppeeexex04', 'ppeexnmnmx04', 'ppemxnmnex04', 'ppeexnenex04', 'ppemexnmx04', 'ppeeexnex04', 'ppeexmxnm04', 'ppeexexne04', 'pptx20', 'ppaaa03']</pre>
optional arguments:	
-h,help clean_process	show this help message and exit Clean the selected process completely before compiling it.
install_openloops	Force installation of OpenLoops, even though openloops exectuable is found under environmental \$PATH variable or path_to_openloops is given in MATRIX_configuration.
agree_to_all	Agree to cite properly all external Codes and automatically skip the licence-agreement dialog.
folder_name_extension	on FOLDER_NAME_EXTENSION Specify an extension for the name of the process folder (ie, <process>+"folder_name_extension", default: <process>+"_MATRIX)"</process></process>
no_compile	Do the process setup (including download/compilation of all external tools), but do not (re-)compile the C++ Code.
old_ginac	Compile with Ginac version 1.6.2 (default).
new_ginac [mars:~/Uni/Own_Codes/p	ublish MATRIX v2.1.0/MATRIX]

./bin/run_process -h

0 🔴 🔵	🖿 Own_Codes — ssh wieseman@th318a.mpp.mpg.de — 86×43
[[wieseman:~/MATRIX_v2_] usage: run_process [-h [[-c [<r< td=""><td><pre>TNG_VVV/MATRIX/run/ppeex02_MATRIX] ./bin/run_process -h] [input_dir INPUT_DIR] [run_mode RUN_MODE] delete_run] [setup_run] [tar_run] change_name_to NEW_NAME] [copy_run_from EXISTING_RUN]] un folder>]</pre></td></r<>	<pre>TNG_VVV/MATRIX/run/ppeex02_MATRIX] ./bin/run_process -h] [input_dir INPUT_DIR] [run_mode RUN_MODE] delete_run] [setup_run] [tar_run] change_name_to NEW_NAME] [copy_run_from EXISTING_RUN]] un folder>]</pre>
MATRIX.	
positional arguments:	
<pre><run folder=""></run></pre>	run folder, must start with run_
optional arguments: -h,help input dir INPUT DI	show this help message and exit
	Specify directory inside input folder from where template MATRIX input files are taken (default: use "default.input.MATRIX" folder)
run_mode RUN_MODE	<pre>Specify run mode (RUN_MODE="run"/"run_grid"/"run_pre"/ "run_pre_and_main"/"run_result"/"run_gnuplot")</pre>
delete_run	Remove run folder (including input/log/result).
setup_run	Setup the run folder, but not start running.
tar_run	Create .tar archive of run folder (including
change name to NEW	NAME
0	Rename run folder (including input/log/result).
copy_run_from EXIS	TING_RUN
	Copy run folder from existing run (including
-c,continue	Continue the previous run from the specified run_mode; important: make sure the inputs are consistent!
[wieseman:~/MATRIX_v2_	TNG_VVV/MATRIX/run/ppeex02_MATRIX]



- many additional command-line options, use "-h" to show all options
- most useful arguments:
 - --agree to all:
 - \rightarrow no need to keep typing "y" for the user agreement
 - --clean process:
- \rightarrow cleans C++ compilation before recompiling (except slow 2-loop amplitude)

- ./matrix ppz01 --agree to all
- ./matrix ppz01 --clean process



- many additional command-line options, use "-h" to show all options
- most useful arguments:

--run_mode \${XX}: ./bin/run_process run_xx --run_mode run_pre_and_main \rightarrow no need to keep typing "y" for the user agreement

--continue:

• • •

[[wieseman:~/MATRIX_v2_TNG_VVV/MATRIX/run/ppeex02_MATRIX/run_test/NNLO.QT-CS/22/RRA.QCD] ls file_parameter.dat grid ppeex02 run.0 subprocesslist.dat test [[wieseman:~/MATRIX_v2_TNG_VVV/MATRIX/run/ppeex02_MATRIX/run_test/NNLO.QT-CS/22/RRA.QCD] rm -rf grid [wieseman:~/MATRIX_v2_TNG_VVV/MATRIX/run/ppeex02_MATRIX/run_test/NNLO.QT-CS/22/RRA.QCD]

./bin/run_process run_xx --run_mode run_grid --continue -> continue run that has crashed (jobs without "final result" in execution file) \rightarrow or rerun part of calculation (e.g. after a fix), just delete folders to be redone:

Own_Codes — ssh wieseman@th318a.mpp.mpg.de — 107×43





- many additional command-line options, use "-h" to show all options
- most useful arguments
- use the code completely without using the shells (I suggest to use a screen or tmux session):
 - ./matrix ppz01 --agree to all
 - ./bin/run process run xx --run mode run

alternatively run in background (not my recommendation): nohup ./bin/run_process run xx --run mode run > f.out &

now let's start playing with the inputs...

- task: increase num. precision of our run from 1% (default) to 0.1%
- don't create a new run, use tip: the old run and just rerun the main run
- you can change the input file tip: directly inside the folder input/run XX/parameter.dat (or use again the interface)
- via run mode run main you tip: can restart just the main run (either inline or via interface)

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 108×44 <<MATRIX–JOBS>> | 2024–08–24 22:43:41 | Queued: 3 | Running: 0 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 22:43:46 Queued: 0 | Running: 3 | Finished: 0 2024-08-24 22:44:01 Running: 2 | Finished: 1 <<MATRIX-JOBS>> | Queued: 0 <<MATRIX-JOBS>> | 2024-08-24 22:44:06 | Queued: 0 | Running: 0 | Finished: 3 <<MATRIX-JOBS>> | 2024-08-24 22:44:06 | Queued: 0 | Running: 0 | Finished: 3 | <<MATRIX-INFO>> All runs successfully finished. <<MATRIX-INFO>> Cleaning previous results (result run)... <<MATRIX-INFO>> Collecting and combining results... <<MATRIX-JOBS>> | 2024-08-24 22:44:06 | Queued: 2 | Running: 0 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 22:44:11 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2024-08-24 22:44:11 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2024-08-24 22:44:11 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-INFO>> Plotting results with gnuplot... <<MATRIX-INFO>> Trying to plot: y_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: n_jets__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <MATRIX-INFO>> Trying to plot: pT_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Combining all pdf files into single file "all_plots.pdf"...

> Final result for: p p --> Z

<MATRIX-RESULT> 1 separate run was made

LO-run <MATRIX-RESULT> PDF: NNPDF31_nlo_as_0118_luxqed <MATRIX-RESULT> Total rate (possibly within cuts): MATRIX-RESULT> <MATRIX-RESULT> L0:4.912e+07 fb +/- 1.3e+05 fb (muR, muF unc.: +11.4% -12.5%) <MATRIX-RESULT> ------<MATRIX-RESULT> All results (including the distributions) can be found in: <MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LC

[bnd005@bnd01 ppz01_MATRIX]\$

QCD and Monte Carlo event generators (Lecture 2 — hands-on session)





• now let's start playing with the inputs...
\$ emacs -nw input/
run_Z_onshell_LO/parameter.dat

Image of the second second





🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44 now let's start playing with the inputs... File Edit Options Buffers Tools Help dynamic scale = 0 # dynamic ren./fac. scale # 0: fixed scale above \$ emacs -nw input/ # 1: invariant mass (Q) of system (of the colourless final states) # 2: transverse mass (mT^2=Q^2+pT^2) of system (of the colourless final st\ ates) run Z onshell LO/parameter.dat factor_central_scale = 1 # relative factor for central scale (important for dynamic scales) # switch for muR/muF uncertainties (0) off; (1) 7-point (default); (2) 9-p\ scale_variation = 1 oint variation > precision LO = 1.e-3variation_factor = 2 # symmetric variation factor; usually a factor of 2 up and down (default) Order-dependent run settings # LO-run run_LO # switch for LO cross section (1) on; (0) off = 1 LHAPDF LO = NNPDF31_nlo_as_0118_luxqed # LO LHAPDF set PDFsubset_L0 # member of LO PDF set = 0 = 1.e-3 # precision of LO cross section precision LO # NLO-run run_NLO_QCD # switch for NLO QCD cross section (1) on; (0) off = 0 run_NLO_EW # switch for NLO EW cross section (1) on; (0) off = 0 LHAPDF_NLO = NNPDF31_nlo_as_0118_luxged # NLO LHAPDF set PDFsubset_NLO = 0 # member of NLO PDF set $precision_NLO_QCD = 1.e-2$ # precision of NLO QCD cross section precision_NLO_EW = 1.e-2 # precision of NLO EW correction # switch to use (2) qT subtraction (1) Catani-Seymour at NLO NLO_subtraction_method = 1 # NNLO-run run NNLO QCD # switch for NNLO QCD cross section (1) on; (0) off = 0 # switch to add NLO EW cross section to NNLO run (1) on; (0) off add_NLO_EW = 0 # note: can be added only if also running NNLO LHAPDF NNLO = NNPDF31_nnlo_as_0118_luxqed # NNLO LHAPDF set PDFsubset NNLO = 0 # member of NNLO PDF set # precision of NNLO QCD cross section precision_NNLO_QCD = 1.e-2 precision_added_EW = 1.e-2 # precision of NLO EW correction in NNLO run # switch to include leading power corrections in qT-subtraction through re\ power_corrections = 0 coil # (not recommended for processes involving photons and heavy quarks) characteristic transverse momentum pT0 used to optimise the generation power_corrections_pT0 = 25. # -UU-:---F1 parameter.dat 12% L36 (Fundamental) -----





- now let's start playing with the inputs...
 \$ emacs -nw input/
 run_Z_onshell_LO/parameter.dat
 > precision_LO = 1.e-3
 - \$./bin/run_process run_XX
 --run_mode run_main

📀 😑 💼 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44

[[bnd005@bnd01 ppz01_MATRIX]\$ emacs -nw input/run_Z_onshell_LO/parameter.dat [bnd005@bnd01 ppz01_MATRIX]\$./bin/run_process run_Z_onshell_LO --run_mode run_main



- now let's start playing with the inputs... emacs -nw input/ \$ run Z onshell LO/parameter.dat > precision LO = 1.e-3
 - ./bin/run process run XX \$ --run mode run main

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 108×44 <<MATRIX-JOBS>> | 2024-08-24 23:03:40 | Queued: 0 | Running: 3 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 23:04:00 | Queued: 0 | Running: 2 | Finished: 1 <<MATRIX-JOBS>> | 2024-08-24 23:04:15 | Queued: 0 | Running: 1 | Finished: 2 <<MATRIX-JOBS>> | 2024-08-24 23:04:25 | Queued: 0 | Running: 0 | Finished: 3 <<MATRIX-JOBS>> | 2024-08-24 23:04:25 | Queued: 0 | Running: 0 | Finished: 3 | <<MATRIX-INFO>> All runs successfully finished. <<MATRIX-INFO>> Cleaning previous results (result run)... <<MATRIX-INFO>> Collecting and combining results... <<MATRIX-JOBS>> | 2024-08-24 23:04:25 | Queued: 2 | Running: 0 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 23:04:30 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-JOBS>> | 2024-08-24 23:04:30 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2024-08-24 23:04:30 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-INFO>> Plotting results with gnuplot... <<MATRIX-INFO>> Trying to plot: y_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: n_jets__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: pT_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Combining all pdf files into single file "all_plots.pdf"...

Final result for: p p --> Z @ 13 TeV LHC

<MATRIX-RESULT> 1 separate run was made

LO-run #-----<MATRIX-RESULT> PDF: NNPDF31_nlo_as_0118_luxqed <MATRIX-RESULT> Total rate (possibly within cuts): MATRIX-RESULT> -----<MATRIX-RESULT> L0:4.927e+07 fb +/- 4.7e+04 fb (muR, muF unc.: +11.4% -12.5%) <MATRIX-RESULT> ------<MATRIX-RESULT> All results (including the distributions) can be found in:

```
<MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LC
[bnd005@bnd01 ppz01_MATRIX]$
```







- now let's start playing with the inputs... emacs -nw input/ \$ run Z onshell LO/parameter.dat > precision LO = 1.e-3
 - ./bin/run process run XX \$ --run mode run main

previous result with 1% precision:

	#\
	# LO-run
	#/
<matrix-result></matrix-result>	PDF: NNPDF31_nlo_as_0118_luxqed
<matrix-result></matrix-result>	Total rate (possibly within cuts):
<matrix-result></matrix-result>	
<matrix-result></matrix-result>	LO:4.912e+07 fb +/- 1.3e+05 fb (muR, muF unc.: +11.4% -12.5%)
<matrix-result></matrix-result>	

mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 108×44 <<MATRIX-JOBS>> | 2024-08-24 23:03:40 | Queued: 0 | Running: 3 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 23:04:00 | Queued: 0 | Running: 2 | Finished: 1 <<MATRIX-JOBS>> | 2024-08-24 23:04:15 | Queued: 0 | Running: 1 | Finished: 2 <<MATRIX-JOBS>> | 2024-08-24 23:04:25 | Queued: 0 | Running: 0 | Finished: 3 <<MATRIX-JOBS>> | 2024-08-24 23:04:25 | Queued: 0 | Running: 0 | Finished: 3 | <<MATRIX-INFO>> All runs successfully finished. <<MATRIX-INFO>> Cleaning previous results (result run)... <<MATRIX-INFO>> Collecting and combining results... <<MATRIX-JOBS>> | 2024-08-24 23:04:25 | Queued: 2 | Running: 0 | Finished: 0 <<MATRIX-JOBS>> | 2024-08-24 23:04:30 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2024-08-24 23:04:30 | Queued: 0 | Running: 0 | Finished: 2 <<MATRIX-JOBS>> | 2024-08-24 23:04:30 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-INFO>> Plotting results with gnuplot... <<MATRIX-INFO>> Trying to plot: y_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: n_jets__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: pT_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Combining all pdf files into single file "all_plots.pdf"... Final result for: p p --> Z @ 13 TeV LHC <MATRIX-RESULT> 1 separate run was made # LO-run <MATRIX-RESULT> PDF: NNPDF31_nlo_as_0118_luxqed <MATRIX-RESULT> Total rate (possibly within cuts):

MATRIX-RESULT> <MATRIX-RESULT> L0:4.927e+07 fb +/- 4.7e+04 fb (muR, muF unc.: +11.4% -12.5%) <MATRIX-RESULT> -

<MATRIX-RESULT> All results (including the distributions) can be found in: <MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LC [bnd005@bnd01 ppz01_MATRIX]\$





now let's start playing with the inputs... \$ emacs -nw input/ run Z onshell LO/parameter.dat > precision LO = 1.e-3

If you did not manage to do so, you the solution to this task also here: /var/bnd/theo/help/solution-3-running with higher precision.sh (execute inside the MATRIX v2.1.0/run/ppz01 MATRIX folder)

previous result with 1% precision:

	#\
	# LO-run
	#/
<matrix-result></matrix-result>	PDF: NNPDF31_nlo_as_0118_luxqed
<matrix-result></matrix-result>	Total rate (possibly within cuts):
<matrix-result></matrix-result>	
<matrix-result></matrix-result>	LO:4.912e+07 fb +/- 1.3e+05 fb (muR, muF unc.: +11.4% -12.5%)
<matrix-result></matrix-result>	

💿 😑 🍵 🛅 mars — bn	d005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be —
< <matrix-jobs>> <<matrix-jobs>></matrix-jobs></matrix-jobs>	2024–08–24 23:03:40 Queued: 0 Running: 3 Finished: 0 2024–08–24 23:04:00 Queued: 0 Running: 2 Finished: 1
< <matrix-jobs>></matrix-jobs>	2024-08-24 23:04:15 Queued: 0 Running: 1 Finished: 2 2024-08-24 23:04:25 Queued: 0 Running: 0 Finished: 3
< <matrix-jobs>></matrix-jobs>	2024-08-24 23:04:25 Queued: 0 Running: 0 Finished: 3
< <matrix-info>></matrix-info>	Cleaning previous results (result run)
< <matrix-info>> <<matrix-jobs>></matrix-jobs></matrix-info>	2024-08-24 23:04:25 Queued: 2 Running: 0 Finished: 0
< <matrix-jobs>> <<matrix-jobs>></matrix-jobs></matrix-jobs>	2024–08–24 23:04:30 Queued: 0 Running: 0 Finished: 2 2024–08–24 23:04:30 Queued: 0 Running: 0 Finished: 2
< <matrix-jobs>></matrix-jobs>	2024–08–24 23:04:30 Queued: 0 Running: 0 Finished: 2



<MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LC [bnd005@bnd01 ppz01_MATRIX]\$

QCD and Monte Carlo event generators (Lecture 2 — hands-on session)

September 6, 2024





now let's start playing with the inputs...

task: start a new run where you turn on NLO and see how the number of jobs changes, repeat this for NNLO (also include NLO EW)
tip: abort run with ctrl-c

(no point of waiting, it will take too long) 💿 😑 💼 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be —

File Edit Options Buffers Tools Help

# NLO-run				
run_NLO_QCD	=	1	#	switch for NLO QCD cross section (1) on; (0) off
run_NLO_EW	=	0	#	switch for NLO EW cross section (1) on; (0) off
LHAPDF_NLO	=	NNPDF31_	nlo	_as_0118_luxqed
PDFsubset_NLO	=	0	#	member of NLO PDF set
precision_NLO_QCD	=	1.e-2	#	precision of NLO QCD cross section
precision_NLO_EW	=	1. e-2	#	precision of NLO EW correction
NLO_subtraction_met	tho	d = 1	#	switch to use (2) qT subtraction (1) Catani-Seymour at NLO
# NNLO-rup				
π NNLO-1011	_	0	#	switch for NNLO OCD cross section (1) on: (0) off
add NIO FW		0	# #	switch to add NLO EW cross section to NNLO run (1) on: (0) off
		0	# #	note: can be added only if also running NNLO
HAPDE NNLO	=	NNPDE31	nn1	$rac{1}{2}$ as 0118 juxged # NNLO HAPDE set
PDFsubset NNLO	=	0	#	member of NNLO PDF set
precision NNLO QCD	=	1.e-2	#	precision of NNLO QCD cross section
precision added EW	=	1.e-2	#	precision of NLO EW correction in NNLO run
power_corrections	=	0	#	switch to include leading power corrections in qT-subtraction
			#	(not recommended for processes involving photons and heavy qua
power corrections p	от0	= 25.	#	characteristic transverse momentum pT0 used to optimise the ge
			#	of the phase space for the integration of the power correction
ld be set				
			#	to the minimum requirement on the transverse momentum of the 2
l state				
			#	(for Drell-Yan for instance this should be the minimum transve
um of the leptons)				
extrapolate_binwise	e =	0	#	switch for bin-wise r_cut extrapolation of distributions
			#	(note: increases written output for distributions by factor of
#		\		
# Settings for fidu	ucia	al cuts		

#	/	
# Jet algorithm		
jet_algorithm = 3	#	(1) Cambridge-Aachen (2) kT (3) anti-kT
<pre>jet_R_definition = 0</pre>	#	(0) pseudo-rapidity (1) rapidity
jet R = 0.4	#	DeltaR

Photon recombination (lepton dressing)

-UU-:---F1 parameter.dat 28% L39

(Fundamental) ---





• now let's start playing with the inputs...
\$ emacs -nw input/
run_Z_onshell_LO/parameter.dat
> run_NLO_QCD = 1

💿 😑 💼 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44

File Edit Options Buffers Tools Help

# NLO-run				
run_NLO_QCD	=	1	#	switch for NLO QCD cross section (1) on; (0) off
run_NLO_EW	=	0	#	switch for NLO EW cross section (1) on; (0) off
LHAPDF_NLO	=	NNPDF31_	nlo	_as_0118_luxqed
PDFsubset_NLO	=	0	#	member of NLO PDF set
precision_NLO_QCD	=	1.e-2	#	precision of NLO QCD cross section
precision_NLO_EW	=	1. e-2	#	precision of NLO EW correction
NLO_subtraction_met	tho	d = 1	#	switch to use (2) qT subtraction (1) Catani-Seymour at NLO
# NNLO-rup				
π NNLO-1011	_	0	#	switch for NNLO OCD cross section (1) on: (0) off
add NIO FW		0	# #	switch to add NLO EW cross section to NNLO run (1) on: (0) off
		0	# #	note: can be added only if also running NNLO
HAPDE NNLO	=	NNPDE31	nn1	$rac{1}{2}$ as 0118 juxged # NNLO [HAPDE set
PDFsubset NNLO	=	0	#	member of NNLO PDF set
precision NNLO QCD	=	1.e-2	#	precision of NNLO QCD cross section
precision added EW	=	1.e-2	#	precision of NLO EW correction in NNLO run
power_corrections coil	=	0	#	switch to include leading power corrections in qT-subtraction
			#	(not recommended for processes involving photons and heavy qua
power corrections p	от0	= 25.	#	characteristic transverse momentum pT0 used to optimise the ge
			#	of the phase space for the integration of the power correction
ld be set				
			#	to the minimum requirement on the transverse momentum of the 2
l state				
			#	(for Drell-Yan for instance this should be the minimum transve
um of the leptons)				
extrapolate_binwise	e =	0	#	switch for bin-wise r_cut extrapolation of distributions
			#	(note: increases written output for distributions by factor of
#		\		
# Settings for fidu	ucia	al cuts		

#	/	
<pre># Jet algorithm</pre>		
jet_algorithm = 3	#	(1) Cambridge-Aachen (2) kT (3) anti-kT
<pre>jet_R_definition = 0</pre>	#	(0) pseudo-rapidity (1) rapidity
$jet_R = 0.4$	#	DeltaR

Photon recombination (lepton dressing)

-UU-:---F1 parameter.dat 28% L39

(Fundamental) _---



- now let's start playing with the inputs...
 \$ emacs -nw input/
 run_Z_onshell_LO/parameter.dat
 > run_NLO_QCD = 1
 - \$./bin/run_process run_XX
 --run_mode run

💿 😑 bir mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44

[[bnd005@bnd01 ppz01_MATRIX]\$ emacs -nw input/run_Z_onshell_LO/parameter.dat [bnd005@bnd01 ppz01_MATRIX]\$./bin/run_process run_Z_onshell_LO --run_mode run

- now let's start playing with the inputs...
 \$ emacs -nw input/
 run_Z_onshell_LO/parameter.dat
 > run_NLO_QCD = 1
 - \$./bin/run_process run_XX
 --run_mode run

```
🖲 😑 💼 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44
                     Version: 2.1.0
                                                               Mar 2023
                  Reference: arXiv:1711.06631
           Munich -- the MUlti-chaNnel Integrator at swiss (CH) precision --
           Automates qT-subtraction and Resummation to Integrate X-sections
                         )==== + | )==== +
                                                )==== +
                                                                      |-)====
               )==== +
                                                            )==== +
                                                    (grazzini@physik.uzh.ch)
           M. Grazzini
           S. Kallweit
                                                   (stefan.kallweit@cern.ch)
            M. Wiesemann
                                                   (marius.wiesemann@cern.ch)
           MATRIX is based on a number of different computations and tools
           from various people and groups. Please acknowledge their efforts
           by citing the references in CITATIONS.bib created with every run.
<<MATRIX-WARN>> Run folder selected: /var/bnd/users/bnd005/Matrix_tutorial/MATRI
               X_v2.1.0/run/ppz01_MATRIX/run_Z_onshell_LO; Previous run in this
               folder will be overwritten.
<<MATRIX-INFO>> Old Run folder overwritten: /var/bnd/users/bnd005/Matrix_tutoria
               1/MATRIX_v2.1.0/run/ppz01_MATRIX/run_Z_onshell_LO.
<<MATRIX-INFO>> Saving previous result...
<<MATRIX-INFO>> Using LHAPDF version 6.5.4...
<<MATRIX-INFO>> Found exported variable $LHAPDF_DATA_PATH with colon-separated
               list: /cvmfs/sft.cern.ch/lcg/external/lhapdfsets/current/:/cvmfs
               /sft.cern.ch/lcg/releases/MCGenerators/lhapdf/6.5.1-389ee/x86_64
               -centos7-gcc11-opt/share/LHAPDF:. Usinig first entry
               /cvmfs/sft.cern.ch/lcg/external/lhapdfsets/current/ as folder
               for download.
```

<<MATRIX-INFO>> All PDF sets already installed. Continuning without download... <<MATRIX-INFO>> Now it's time for running... <<MATRIX-INFO>> Running in multicore mode...

```
<<MATRIX-INFO>> Starting grid setup (warmup)...
```

```
<<MATRIX-JOBS>> | 2024-08-24 23:06:04 | Queued: 15 | Running: 0 | Finished: 0 | <<MATRIX-JOBS>> | 2024-08-24 23:06:09 | Queued: 0 | Running: 15 | Finished: 0 |
```





- now let's start playing with the inputs...
 - \$ emacs -nw input/
 - run_Z_onshell_LO/parameter.dat
 - $> run_NLO_QCD = 1$
 - \$./bin/run_process run_XX
 --run_mode run
 - > ctrl-c (to stop the code)







- now let's start playing with the inputs...
 - \$ emacs -nw input/
 - run_Z_onshell_LO/parameter.dat
 - $> run_NNLO_QCD = 1$
 - $> add_NLO_EW = 1$

🗛 👝 🦱 📰 mare — hnd006	ahn	d01./var/bp	ducare	/bnd005/Matrix_tutorial/MATRIX_v210/run/pnz01_MATRIX_esh.bnd005@bnd01.iiba.ac.ba_1
			ujuseis	
File Edit Options	Bufi	fers Too	ls He	elp
dynamic_scale =	= (9	#	dynamic ren./fac. scale
			#	0: fixed scale above
			#	1: invariant mass (Q) of system (of the colourless final state
			#	2: transverse mass (mT^2=Q^2+pT^2) of system (of the colourles
ates)				
factor_central_sca	le =	= 1	#	relative factor for central scale (important for dynamic scale
scale_variation	= 2	L	#	switch for muR/muF uncertainties (0) off; (1) 7-point (default
oint variation				
variation_factor =	= 2	2	#	symmetric variation factor; usually a factor of 2 up and down
#			\	
# Order-dependent :	run	setting	s	
#			/	
# LO-run				
run_LO	=	1	#	switch for LO cross section (1) on; (0) off
LHAPDF_LO	=	NNPDF31	_nlo	as_0118_luxqed
PDFsubset_L0	=	0	#	member of LO PDF set
precision_LO	=	1.e-3	#	precision of LO cross section
# NLO-run				
run NLO QCD	=	1	#	switch for NLO QCD cross section (1) on; (0) off
run NLO EW	=	1	#	switch for NLO EW cross section (1) on; (0) off
LHAPDF NLO	=	NNPDF31	nlo	as 0118 luxged # NLO LHAPDF set
PDFsubset NLO	=	0		member of NLO PDF set
precision NLO QCD	=	1.e-2	#	precision of NLO QCD cross section
precision NLO EW	=	1.e-2	#	precision of NLO EW correction
NLO subtraction me	tho	d = 1	#	switch to use (2) gT subtraction (1) Catani-Sevmour at NLO
# NNLO-run				
run NNLO QCD	=	1	#	switch for NNLO QCD cross section (1) on: (0) off
add NLO EW		1	#	switch to add NLO EW cross section to NNLO run (1) on: (0) off
			#	note: can be added only if also running NNLO
HAPDE NNI O	=	NNPDF31	nnlo	as 0118 luxged # NNLO LHAPDE set
PDFsubset NNLO	=	0	#	member of NNLO PDF set
precision NNLO QCD	=	1.e-2	#	precision of NNLO QCD cross section
precision_added_EW	=	1.e-2	#	precision of NLO FW correction in NNLO run
power corrections	=	0	" #	switch to include leading nower corrections in aT-subtraction
coil			"	
			#	(not recommended for processes involving photops and beavy qua
nower corrections	nT0	- 25	" #	characteristic transverse momentum pTO used to optimise the go
		- dat	12%	40 (Eundamental)
	6161	ual	12/0	



- now let's start playing with the inputs...
 - \$ emacs -nw input/
 - run_Z_onshell_LO/parameter.dat
 - $> run_NNLO_QCD = 1$
 - > add NLO EW = 1
 - \$./bin/run_process run_XX
 --run_mode run
 - > ctrl-c (to stop the code)







now let's start playing with the inputs... emacs -nw input/ \$ run Z onshell LO/parameter.dat > run NNLO QCD = 1

If you did not manage to do so, you the solution to this task also here: /var/bnd/theo/help/solution-4-running with higher orders.sh (execute inside the MATRIX v2.1.0/run/ppz01 MATRIX folder)



```
1/MATRIX_v2.1.0/run/ppz01_MATRIX/run_Z_onshell_LO.
<<MATRIX-INFO>> Using LHAPDF version 6.5.4...
<<MATRIX-INFO>> Found exported variable $LHAPDF_DATA_PATH with colon-separated
                list: /cvmfs/sft.cern.ch/lcg/external/lhapdfsets/current/:/cvmfs
                /sft.cern.ch/lcg/releases/MCGenerators/lhapdf/6.5.1-389ee/x86_64
                -centos7-gcc11-opt/share/LHAPDF:. Usinig first entry
                /cvmfs/sft.cern.ch/lcg/external/lhapdfsets/current/ as folder
                for download.
<<MATRIX-INFO>> All PDF sets already installed. Continuning without download...
<<MATRIX-INFO>> Now it's time for running...
<<MATRIX-INFO>> Running in multicore mode...
<<MATRIX-INFO>> Starting grid setup (warmup)...
 MATRIX-JOBS>> | 2024-08-24 23:19:16 | Queued: 104 | Running: 0 | Finished: 0 |
<<MATRIX-JOBS>> | 2024-08-24 23:19:16 | Queued: 48 | Running: 56 | Finished: 0
<<MATRIX-JOBS>> | 2024-08-24 23:19:17 | Queued: 48 | Running: 56 | Finished: 0 |
^CYou pressed ctrl-c!
 <MATRIX-ERROR>> Removing lock file...
<MATRIX-ERROR>> Exiting...
[bnd005@bnd01 ppz01_MATRIX]$
```



let's do something more useful and compare to actual LHC data!

task: consider recent inclusive measurement at 8 TeV from ATLAS of Z rapidity (y) and transverse momentum (p_T) distribution and calculate LO result with MATRIX with the following steps: I. change energy to 8 TeV 2. implement y distribution 3. perform LO run 4. compare to data from: /var/bnd/theo/matrix/ATLAS DY data/ y Z-ATLAS data.dat



https://www.hepdata.net/record/ins2698794

or download and extract:

wget https://wwwth.mpp.mpg.de/members/wieseman/download/ lectures and talks/BND Summer School Lecture/matrix files.tar

compare to actual LHC data!

task: consider recent inclusive measurement at 8 TeV from ATLAS of Z rapidity (y) and transverse momentum (p_T) distribution and calculate LO result with MATRIX with the following steps: I. change energy to 8 TeV 2. implement y distribution 3. perform LO run 4. compare to data from: /var/bnd/theo/matrix/ATLAS DY data/ y Z-ATLAS data.dat




let's do something more useful and compare to actual LHC data!

task: consider recent inclusive measurement at 8 TeV from ATLAS of Z rapidity (y) and transverse momentum (p_T) distribution and calculate LO result with MATRIX with the following steps: I. change energy to 8 TeV 2. implement y distribution 3. perform LO run 4. compare to data

💿 😑 🍵 🔤 mars — bnd005@bnd01:/var/bnd/	/user	s/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 1
File Edit Options Buffers Tool	ls H	elp

# MATRIX input parameter #		
+++++++++++++++++++++++++++++++++++++++		
#\		
# General run settings		
#/		
orocess_class = pp-z+X	#	process id
E = 4000.	#	energy per beam
coll_choice = 1	#	(1) PP collider; (2) PPbar collider
ohoton_induced = 1	#	switch to turn on (1) and off (0) photon-induced contributions
enhance_tails = 0	#	switch to improve statistics in tail of distributions (a facto
lower)		
#\		
# Scale settings		
#/		
scale_ren = 91.1876	#	renormalization (muR) scale
scale_fact = 91.1876	#	factorization (muF) scale
dynamic_scale = 0	#	dynamic ren./fac. scale
	#	0: fixed scale above
	#	1: invariant mass (Q) of system (of the colourless final state
	#	2: transverse mass (mT^2=Q^2+pT^2) of system (of the colourles
ates)		
factor_central_scale = 1.0	#	relative factor for central scale (important for dynamic scale
scale_variation = 1	#	switch for muR/muF uncertainties (0) off; (1) 7-point (default
pint variation		
variation_factor = 2	#	symmetric variation factor; usually a factor of 2 up and down
#	\	
# Order-dependent run settings	s	
#	/	
# LO-run		
$run_L0 = 1$	#	switch for LO cross section (1) on; (0) off
LHAPDF_LO = NNPDF31_	_nlo	_as_0118_luxqed
PDFsubset_L0 = 0	#	member of LO PDF set
precision_LO = 1.e-3	#	precision of LO cross section
# NLO-run		
-UU-:F1 parameter.dat T	Гор	L9 (Fundamental)





let's do something more useful and compare to actual LHC data!

task: consider recent inclusive measurement at 8 TeV from ATLAS of Z rapidity (y) and transverse momentum (p_T) distribution and calculate LO result with MATRIX with the following steps: I. change energy to 8 TeV 2. implement y distribution 3. perform LO run 4. compare to data

```
🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44
 File Edit Options Buffers Tools Help
MATRIX distribution definition #
 *****
# In this file you can customize the distributions created during the run (examples below)
# please read the INSTRUCTIONS at the END OF THIS FILE...
# Info
# Total rates and jet multiplicities (possibly within cuts) will automatically be included
# Add/remove arbitrary distribution-blocks, but always add/remove a full block.
# define distributions
# transverse momentum of the Z boson regularly binned in 200 bins from 0–1000 GeV (ie, 5 GeV bins)
distributionname = pT_Z
distributiontype = pT
particle 1
                 = z 1
startpoint
                 = 0.
endpoint
                 = 1000.
binnumber
                 = 200
# rapidity of the Z boson regularly binned from -10 to 10 in 0.2 steps
distributionname = y_Z
distributiontype = y
particle 1
                 = z 1
startpoint
                 = -10.
endpoint
                 = 10.
binwidth
                 = 0.2
# rapidity of the Z boson binned as in ATLAS 8TeV measurement
distributionname = y_Z-ATLAS
distributiontype = absy
particle 1
                 = z 1
                = irregular
binningtype
                 = 0.0:0.4:0.8:1.2:1.6:2.0:2.4:2.8:3.6
edges
# Syntax
                              Top L38
                                         (Fundamental) ----
            distribution.dat
 -UU-:---F1
```





let's do something more useful and compare to actual LHC data!

task: consider recent inclusive measurement at 8 TeV from ATLAS of Z rapidity (y) and transverse momentum (p_T) distribution and calculate LO result with MATRIX with the following steps: I. change energy to 8 TeV 2. implement y distribution 3. perform LO run 4. compare to data

🖥 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44 <<MATRIX-JOBS>> | 2024-08-25 00:07:26 | Queued: 0 | Running: 0 | Finished: 3 | <<MATRIX-JOBS>> | 2024-08-25 00:07:26 | Queued: 0 | Running: 0 | Finished: 3 | <MATRIX-INFO>> All runs successfully finished. <MATRIX-INFO>> Cleaning previous results (result run)... <MATRIX-INFO>> Collecting and combining results... <<MATRIX-JOBS>> | 2024-08-25 00:07:26 | Queued: 2 | Running: 0 | Finished: 0 | <<MATRIX-JOBS>> | 2024-08-25 00:07:31 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-JOBS>> | 2024-08-25 00:07:31 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-JOBS>> | 2024-08-25 00:07:31 | Queued: 0 | Running: 0 | Finished: 2 | <<MATRIX-INFO>> Plotting results with gnuplot... <<MATRIX-INFO>> Trying to plot: y_Z-ATLAS__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: y_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: n_jets__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Trying to plot: pT_Z__LO <<MATRIX-INFO>> Running gnuplot... <<MATRIX-INFO>> Plot successfully generated. <<MATRIX-INFO>> Combining all pdf files into single file "all_plots.pdf"...

> Final result for: p p --> Z @ 8 TeV LHC

<MATRIX-RESULT> 1 separate run was made

#____ # L0-run <MATRIX-RESULT> PDF: NNPDF31_nlo_as_0118_luxged <MATRIX-RESULT> Total rate (possibly within cuts): MATRIX-RESULT> <MATRIX-RESULT> L0:2.863e+07 fb +/- 2.7e+04 fb (muR, muF unc.: +8.3% -9.5%) <MATRIX-RESULT> ------<MATRIX-RESULT> All results (including the distributions) can be found in: <MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_L

QCD and Monte Carlo event generators (Lecture 2 — hands-on session)



- let's do something more useful and compare to actual LHC data!
 - task: consider recent inclusive measurement at 8 TeV from
 - - (execute inside the MATRIX v2.1.0/run/ppz01 MATRIX folder)
 - following steps:
 - I. change energy to 8 TeV
 - 2. implement y distribution
 - 3. perform LO run
 - 4. compare to data

💿 😑 🔵 🔯 mars — bno	d005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be —
< <matrix-jobs>></matrix-jobs>	<pre> 2024-08-25 00:07:26 Queued: 0 Running: 0 Finished: 3 </pre>
< <matrix-jobs>></matrix-jobs>	2024-08-25 00:07:26 Queued: 0 Running: 0 Finished: 3
< <matrix-info>></matrix-info>	All runs successfully finished.
< <matrix-info>></matrix-info>	Cleaning previous results (result run)
< <matrix-info>></matrix-info>	Collecting and combining results
< <matrix-jobs>></matrix-jobs>	2024-08-25 00:07:26 Queued: 2 Running: 0 Finished: 0
< <matrix-jobs>></matrix-jobs>	2024-08-25 00:07:31 Queued: 0 Running: 0 Finished: 2
< <matrix-jobs>></matrix-jobs>	2024-08-25 00:07:31 Queued: 0 Running: 0 Finished: 2
< <matrix-jobs>></matrix-jobs>	2024-08-25 00:07:31 Queued: 0 Running: 0 Finished: 2
< <matrix-jobs>></matrix-jobs>	Plotting results with gnuplot
< <matrix-info>> <<matrix-info>></matrix-info></matrix-info>	Running gnuplot

If you did not manage to do so, you the solution to this task also here:

/var/bnd/theo/help/solution-5-comparison to ATLAS data.sh

Final result for:

<MATRIX-RESULT> 1 separate run was made

NNPDF31 nlo as 0118 luxged <MATRIX-RESULT> Total rate (possibly within cuts): <MATRIX-RESULT> L0:2.863e+07 fb +/- 2.7e+04 fb (muR, muF unc.: +8.3% -9.5%) <MATRIX-RESULT> ------<MATRIX-RESULT> All results (including the distributions) can be found in: <MATRIX-RESULT> /var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_L

QCD and Monte Carlo event generators (Lecture 2 — hands-on session)



let's do something more useful and compare to actual LHC data!

task: consider recent inclusive measurement at 8 TeV from ATLAS of Z rapidity (y) and transverse momentum (p_T) distribution and calculate LO result with MATRIX with the following steps: I. change energy to 8 TeV 2. implement y distribution 3. perform LO run 4. compare to data

💿 😑 💿 🔤 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX — ssh bnd005@bnd01.iihe.ac.be — 107×44 [[bnd005@bnd01 ppz01_MATRIX]\$ cd result/run_Z_onshell_L0/L0-run/distributions__L0/

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let's do something more useful and compare to actual LHC data!

task: consider recent inclusive measurement at 8 TeV from ATLAS of Z rapidity (y) and transverse momentum (p_T) distribution and calculate LO result with MATRIX with the following steps: I. change energy to 8 TeV 2. implement y distribution 3. perform LO run 4. compare to data

💿 😑 💼 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LO/LO-run/distributions__LO —..

[bnd005@bnd01 ppz01_MATRIX]\$ cd result/run_Z_onshell_LO/LO-run/distributions__LO/ [bnd005@bnd01 distributions__LO]\$ ls n_jets__LO.dat pT_Z__LO.dat total_rate__LO.dat y_Z-ATLAS__LO.dat y_Z__LO.dat [bnd005@bnd01 distributions__LO]\$



let's do something more useful and compare to actual LHC data!

task: consider recent inclusive measurement at 8 TeV from ATLAS of Z rapidity (y) and transverse momentum (p_T) distribution and calculate LO result with MATRIX with the following steps: I. change energy to 8 TeV 2. implement y distribution 3. perform LO run 4. compare to data

💿 😑 🔤 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LO/LO-run/distributions__LO —..

[[bnd005@bnd01 ppz01_MATRIX]\$ cd result/run_Z_onshell_LO/LO-run/distributions__LO/ [[bnd005@bnd01 distributions__LO]\$ ls n_jets__LO.dat pT_Z__LO.dat total_rate__LO.dat y_Z-ATLAS__LO.dat y_Z__LO.dat

[[bnd005@bnd01 distributions__LO]\$ emacs -nw y_Z-ATLAS__LO.dat 📕



let's do something more useful and compare to actual LHC data!

•	😑 🔵 🛅 mars	— bnd005@bnd01:/v	var/bnd/users/bnd005/Matri	x_tutorial/MATRIX_v2	2.1.0/run/ppz01_MATRI	X/result/run_Z_onshe	ll_LO/LO-run/distributi	ionsLO — ssh bnd0	05@bnd01.iihe.ac.l
Fi	le Edit Opt	ions Buffers To	ools Help						
#	left-edge	right-edge	scale-central c	entral—error	scale-min	min-error	scale-max	max-error	rel-down
	0	0.4	9568545.5	29160.3	8498220.1	25956.8	10522877.	32059.6	-11.19%
	0.4	0.8	9457907.5	29396.6	8415650.7	26334.7	10385636.	32118.3	-11.02%
	0.8	1.2	9269091.2	30938.0	8274944.5	27831.1	10151223.	33680.1	-10.73%
	1.2	1.6	8909453.2	40351.2	7990765.3	36501.2	9721126.6	43722.1	-10.31%
	1.6	2	8554068.6	37922.6	7716082.1	34401.6	9290072.7	40996.2	-9.80%
	2	2.4	7999456.6	26386.3	7268964.1	24008.3	8634291.1	28458.0	-9.13%
	2.4	2.8	7186338.0	31852.7	6591525.4	29136.3	7693900.5	34193.4	-8.28%
	2.8	3.6	4605174.2	10158.4	4305013.1	9435.54	4847905.5	10757.6	-6.52%
	L			a domonto 7)					
-00	J-:Fl d of buffor	y_Z-ATLASLU.C	dat All L10 (Ful	ndamental)					
End	a or burrer		ing stops:						
			ing steps.						
		I. char	nge energy to	o 8 TeV					
			0 0/	•					
		2. impl	ement y dist	ribution					
		3. perf	orm LO run						
		4 com	nare to data						
			pare lo uala						

🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LO/LO-run/distributions__LO —...

[[bnd005@bnd01 ppz01_MATRIX]\$ cd result/run_Z_onshell_L0/L0-run/distributions__L0/ [[bnd005@bnd01 distributions__L0]\$ ls n_jets__LO.dat pT_Z__LO.dat total_rate__LO.dat y_Z-ATLAS__LO.dat y_Z__LO.dat [[bnd005@bnd01 distributions__LO]\$ emacs -nw y_Z-ATLAS__LO.dat



let's do something more useful and compare to actual LHC data!

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Fi	le Edit Opt:	ions Buffers	Tools Help						
#	left-edge	right-edge	scale-central	central-error	scale-m	in min-error	scale-max	max-error	rel—down
	0	0.4	9568545.5	29160.3	8498220	.1 25956.8	10522877.	32059.6	-11.19%
	0.4	0.8	9457907.5	29396.6	8415650	.7 26334.7	10385636.	32118.3	-11.02%
	0.8	1.2	9269091.2	30938.0	8274944	.5 27831.1	10151223.	33680.1	-10.73%
	1.2	1.6	8909453.2	40351.2	7990765	.3 36501.2	9721126.6	43722.1	-10.31%
	1.6	2	8554068.6	37922.6	7716082	.1 34401.6	9290072.7	40996.2	-9.80%
	2	2.4	7999456.6	26386.3	7268964	.1 24008.3	8634291.1	28458.0	-9.13%
	2.4	2.8	7186338.0	31852.7	6591525	.4 29136.3	7693900.5	34193.4	-8.28%
	2.8	3.6	4605174.2	10158.4	4305013	.1 9435.54	4847905.5	10757.6	-6.52%
–U	U-:F1 y	y_Z-ATLASLO	.dat All L10	(Fundamental) -					
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	le Edit Ont	ione Dufford		/		ATLAS C	lata		
F1	le Edit Opt	right odgo	Tools Help	total arrar l					
#	Ter L-edge	right-edge							
	0	0.4	307.10Z	0.010232	6.32312				
	0.4	0.0	303.10Z	0.0120//	6.30074				
	0.0	1.2	343.70J 226 105	0.014505	6 05151				
	1.2	2.0	330.175 222 / 02	0.031117	5 90/40				
	1.0	2	322.403	0.00/200	5.00407				
	2	2.4	202.973	1,222500	5.4/151 / 01754				
	2.4	2.0	2/3.190	1 4/7900	4.91/00 2 11700				
	2.0	3.0	1/3.1/1	1.440040	3.11/00				
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- En	d of buffor	y_Z-ATLASua	La.ual AII LIU	(Fundamental)					
	u or burrer								

imars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LO/LO-run/distributions__LO —...

[[bnd005@bnd01 ppz01_MATRIX]\$ cd result/run_Z_onshell_L0/L0-run/distributions__L0/ [[bnd005@bnd01 distributions__LO]\$ ls n_jets__LO.dat pT_Z__LO.dat total_rate__LO.dat y_Z-ATLAS__LO.dat y_Z__LO.dat [[bnd005@bnd01 distributions__LO]\$ emacs -nw y_Z-ATLAS__LO.dat





let's do something more useful and compare to actual LHC data!

•	😑 🔵 🛅 mars -	— bnd005@bnd01:/va	r/bnd/users/bnd005/Ma	atrix_tutorial/MATRIX	_v2.1.0/run/ppz01_MA	TRIX/result/run_Z_onshell	_LO/LO-run/distributi	ionsLO — ssh bnd0	05@bnd01.iihe.ac.
Fi	le Edit Opt:	ions Buffers Too	ls Help						
#	left-edge	right-edge	scale-central	central-error	scale-min	min-error	scale-max	max-error	rel-down
	0	0.4	9568545.5	29160.3	8498220.1	25956.8	10522877.	32059.6	-11.19%
	0.4	0.8	9457907.5	29396.6	8415650.7	26334.7	10385636.	32118.3	-11.02%
	0.8	1.2	9269091.2	30938.0	8274944.5	27831.1	10151223.	33680.1	-10.73%
	1.2	1.6	8909453.2	40351.2	7990765.3	36501.2	9721126.6	43722.1	-10.31%
	1.6	2	8554068.6	37922.6	7716082.1	34401.6	9290072.7	40996.2	-9.80%
	2	2.4	7999456.6	26386.3	7268964.1	24008.3	8634291.1	28458.0	-9.13%
	2.4	2.8	7186338.0	31852.7	6591525.4	29136.3	7693900.5	34193.4	-8.28%
	2.8	3.6	4605174.2	10158.4	4305013.1	9435.54	4847905.5	10757.6	-6.52%
-Ul	U-:F1 y	y_Z-ATLASLO.da	t All L10 (Fundamental)					
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		- bhuoos@bhuo1./vai,			/2.1.0/run/pp20	TLAS dai			
Fi	le Edit Opt	ions Buffers Too	ls Help						
#	left-edge	right-edge exp	-cross-section	total-error lum	il-error				
	0	0.4	357.152	0.610232	6.52312				
	0.4	0.8	353.152	0.612877	6.35674	irct hin $(0 <$			
	0.8	1.2	345.985	0.614565	6.22773	$ SUDII (O \geq$	$ y_Z \ge 0$	·-+).	
	1.2	1.6	336.195	0.631117	6.05151				
	1.6	2	322.483	0.867255	5.80469	\frown	σ (nn	$\langle 7 \rangle -$	0569514
	2	2.4	303.973	1.222500	5.47151		$o_{\rm LO}(pp)$	$\rightarrow \angle) =$	900004.
	2.4	2.8	273.198	1.477950	4.91756				
	2.8	3.6	173.171	1.448840	3.11708			$\mathcal{Q} + \mathcal{Q} - \mathbf{i}$	257 150
						lata: σ_{ATT}	$AS(pp \rightarrow q$		337.132
-U	U-:F1	y_Z-ATLASdata.	dat All L10	(Fundamental) –					
En	d of buffer					atura 2 hands on sassion)		Santambar 6 20	24

🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LO/LO-run/distributions__LO —...

[[bnd005@bnd01 ppz01_MATRIX]\$ cd result/run_Z_onshell_L0/L0-run/distributions__L0/ [[bnd005@bnd01 distributions__L0]\$ ls n_jets__LO.dat pT_Z__LO.dat total_rate__LO.dat y_Z-ATLAS__LO.dat y_Z__LO.dat [[bnd005@bnd01 distributions__LO]\$ emacs -nw y_Z-ATLAS__LO.dat





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let's do something more useful and compare to actual LHC data!

•	😑 🔵 🛅 mars -	— bnd005@bnd01:/va	ar/bnd/users/bnd005/M	atrix_tutorial/MATRIX	_v2.1.0/run/ppz01_MA	TRIX/result/run_Z_onshell	_LO/LO-run/distributi	ionsLO — ssh bnd0	05@bnd01.iihe.ac.l
Fi	le Edit Opt:	ions Buffers Too	ols Help						
#	left-edge	right-edge	scale-central	central-error	scale-min	min-error	scale-max	max-error	rel-down
	0	0.4	9568545.5	29160.3	8498220.1	25956.8	10522877.	32059.6	-11.19%
	0.4	0.8	9457907.5	29396.6	8415650.7	26334.7	10385636.	32118.3	-11.02%
	0.8	1.2	9269091.2	30938.0	8274944.5	27831.1	10151223.	33680.1	-10.73%
	1.2	1.6	8909453.2	40351.2	7990765.3	36501.2	9721126.6	43722.1	-10.31%
	1.6	2	8554068.6	37922.6	7716082.1	34401.6	9290072.7	40996.2	-9.80%
	2	2.4	7999456.6	26386.3	7268964.1	24008.3	8634291.1	28458.0	-9.13%
	2.4	2.8	7186338.0	31852.7	6591525.4	29136.3	7693900.5	34193.4	-8.28%
	2.8	3.6	4605174.2	10158.4	4305013.1	9435.54	4847905.5	10757.6	-6.52%
-U	U-:F1 y	y_Z-ATLASLO.da	at All L10 (Fundamental)					
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					2.1.0/i dii/pp20	TLAS dat	a		
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#	left-edge	right-edge exp	p-cross-section	total—error lum	i-error				
	0	0.4	357.152	0.610232	6.52312				
	0.4	0.8	353.152	0.612877	6.35674	ret hin (0 <			
	0.8	1.2	345.985	0.614565	6.22773	1 SC DIII ($0 \geq$	$ y_Z \ge 0$	·-+).	
	1.2	1.6	336.195	0.631117	6.05151				
	1.6	2	322.483	0.867255	5.80469	\frown .		$\langle 7 \rangle -$	0569 51
	2	2.4	303.973	1.222500	5.47151		$o_{\rm LO}(pp)$	$\rightarrow Z) =$	900.04
	2.4	2.8	273.198	1.477950	4.91756				
	2.8	3.6	173.171	1.448840	3.11708			$\rho + \rho - \gamma$	257 150
						ata: $\sigma_{\Delta TI}$	$AS(pp \rightarrow qq)$		337.132
–U	U-:F1	y_Z-ATLASdata.	dat All L10	(Fundamental) –					
En	d of buffer					atura 2 handa an agazian)		Sontombor 6 20	24

🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LO/LO-run/distributions__LO —...

[[bnd005@bnd01 ppz01_MATRIX]\$ cd result/run_Z_onshell_L0/L0-run/distributions__L0/ [[bnd005@bnd01 distributions__L0]\$ ls n_jets__LO.dat pT_Z__LO.dat total_rate__LO.dat y_Z-ATLAS__LO.dat y_Z__LO.dat [[bnd005@bnd01 distributions__LO]\$ emacs -nw y_Z-ATLAS__LO.dat





let's do something more useful and compare to actual LHC data!

•	😑 🔵 🛅 mars	— bnd005@bnd01:/var/	bnd/users/bnd005/M	atrix_tutorial/MATR	RIX_v2.1.0/run/ppz01_	MATRIX/result/run_Z_on	shell_LO/LO-run/distribu	tionsLO — ssh bnd0	05@bnd01.iihe.ac.b
Fil	le Edit Opt	ions Buffers Tool	s Help						
#	left-edge	right-edge	scale-central	central-error	scale-m	in min-error	scale-max	max-error	rel-down
	0	0.4	9568545.5	29160.3	8 8498220	.1 25956.8	10522877.	32059.6	-11.19%
	0.4	0.8	9457907.5	29396.6	8415650	.7 26334.7	10385636.	32118.3	-11.02%
	0.8	1.2	9269091.2	30938.0	8274944	.5 27831.1	10151223.	33680.1	-10.73%
	1.2	1.6	8909453.2	40351.2	2 7990765	.3 36501.2	9721126.6	43722.1	-10.31%
	1.6	2	8554068.6	37922.6	5 7716082	.1 34401.6	9290072.7	40996.2	-9.80%
	2	2.4	7999456.6	26386.3	7268964	.1 24008.3	8634291.1	28458.0	-9.13%
	2.4	2.8	7186338.0	31852.7	6591525	.4 29136.3	7693900.5	34193.4	-8.28%
	2.8	3.6	4605174.2	10158.4	4305013	.1 9435.54	4847905.5	10757.6	-6.52%
-UL	J-:F1	y_Z-ATLASL0.dat	All L10 (Fundamental) -					
Enc	d of buffer								
	👝 🦲 🕅 mars	- bnd005@bnd01·/var/k	ond/users/bnd005/Ma	trix tutorial/MATRIX	$\sqrt{\sqrt{210/r_{\rm un}/n_{\rm n}}}$		B	$R(Z \rightarrow \mathcal{T}')$	$t) \simeq 3.$
						ATLAS d	ata		
F1.	le Edit Opt	ions Buffers Tool	s He⊥p						
#	lett-edge	right-edge exp-	cross-section	total-error 1	umi-error				
	0	0.4	357.152	0.610232	6.52312				
	0.4	0.8	353.152	0.0128//	6.356/4	first hin (0)	$< v_{-} < ($		
	0.8	1.2	345.985	0.014505	0.22//3		$\rightarrow YZ \rightarrow 0$	J	
	1.2	1.0	330.195	0.03111/	6.05151				
	1.0		322.483	0.80/255	5.80469		σ (pr	$\rightarrow 7) -$	0568 51
	2	2.4	303.973	1.222500	5.4/151		$o_{LO}(PP)$		9JU0.J4
	2.4	2.8	2/3.198	1.4//950	4.91/56				
	2.8	3.6	1/3.1/1	1.448840	3.11/08	data: c	$(\mathbf{n}\mathbf{n})$	$\rho + \rho - \gamma - \gamma$	257 150
			at 11110	(Fundamental)		Uala. OAT	$TLAS(PP \rightarrow$		JJ/.1JZ
-0	U-:FI d_of_buffer	y_Z-AILASdata.d	at ALL LIO	(Fundamental)					
EN	u or burrer					(Lastura) hands on sass	sion)	Sontombor 6 20	

🛅 mars — bnd005@bnd01:/var/bnd/users/bnd005/Matrix_tutorial/MATRIX_v2.1.0/run/ppz01_MATRIX/result/run_Z_onshell_LO/LO-run/distributions__LO —...

[[bnd005@bnd01 ppz01_MATRIX]\$ cd result/run_Z_onshell_L0/L0-run/distributions__L0/ [[bnd005@bnd01 distributions__LO]\$ ls n_jets__LO.dat pT_Z__LO.dat total_rate__LO.dat y_Z-ATLAS__LO.dat y_Z__LO.dat [[bnd005@bnd01 distributions__LO]\$ emacs -nw y_Z-ATLAS__LO.dat





let's do something more useful and compare to actual LHC data!

•	😑 🔵 🛅 mars -	— bnd005@bnd01:/var/b	ond/users/bnd005/M	atrix_tutorial/MATR	RIX_v2.1.0/run/ppz01_	_MATRIX/result/run_Z_on	shell_LO/LO-run/distribu	ıtionsLO — ssh bnd0	05@bnd01.iihe.ac.b
Fi:	le Edit Opt	ions Buffers Tools	s Help						
#	left-edge	right-edge	scale-central	central-error	scale-m	in min-error	scale-max	max-error	rel-down
	0	0.4	9568545.5	29160.3	8 8498220	.1 25956.8	10522877.	32059.6	-11.19%
	0.4	0.8	9457907.5	29396.6	6 8415650	.7 26334.7	10385636.	32118.3	-11.02%
	0.8	1.2	9269091.2	30938.0	8274944	.5 27831.1	10151223.	33680.1	-10.73%
	1.2	1.6	8909453.2	40351.2	2 7990765	.3 36501.2	9721126.6	43722.1	-10.31%
	1.6	2	8554068.6	37922.6	5 7716082	.1 34401.6	9290072.7	40996.2	-9.80%
	2	2.4	7999456.6	26386.3	3 7268964	.1 24008.3	8634291.1	28458.0	-9.13%
	2.4	2.8	7186338.0	31852.7	6591525	.4 29136.3	7693900.5	34193.4	-8.28%
	2.8	3.6	4605174.2	10158.4	4305013	.1 9435.54	4847905.5	10757.6	-6.52%
-Ul	U-:F1	y_Z-ATLASL0.dat	All L10 (Fundamental) -					
End	d of buffer								
•	🔒 🦲 📷 mars	— bnd005@bnd01:/var/bi	nd/users/bnd005/Ma	trix tutorial/MATRIX	(v2.1.0/run/ppz0			$R(Z \rightarrow t')$	$t) \simeq 3.$
			najasei sįbilao o ojina			ATLAS d	ata		
F1	le Edit Opt	ions Butters loois	в не⊥р	+ - + - 1 · · · · · · · · · · · · · · · · · ·					
H [#]	Tert-eage	right-eage exp-c	cross-section	total-error I	umi-error				
	0	0.4	357.152	0.010232	0.52312				
	0.4	0.0	303.10Z	0.0120//	0.300/4	first hin (1)	$< v_{-} <$	(14)	
	0.0 1 0	1.2	343.70J 226 105	0.014000	6.22/75		$\rightarrow IJZI \rightarrow I$	••••	
	1.2	1.0	330.175	0.031117	5 80/60				
	2.0	2 /	302 073	1 222500	5.60407	$\int \mathbf{O} \cdot \mathbf{\sigma} = \mathbf{O}$	$nn \rightarrow 7 \rightarrow$	$(e^+e^-) =$	321 503
	2 /	2.4	273 108	1 /77050	4 01756				
	2.4	2.0	173 171	1 448840	3 11708				
	2.0	5.0	1/0.1/1	1.440040	3.11/00	data o.	$$ $(nn \rightarrow$	$(\mathcal{P}^+ \mathcal{P}^-)$	357 152
-11	U-:F1	v Z-ATI AS data da	at A]] 10	(Eundamental)		Gata. OAT	CLAS (PP)		557.152
- En	d of buffer			(Fundamentar)					
	a or barrer				100	(Lastura) hands on sage		Sontombor 6 20	$\mathbf{)}24$

[[bnd005@bnd01 distributions__LO]\$ ls



let's do something more useful and compare to actual LHC data!

•	😑 🔵 🛅 mars -	— bnd005@bnd01:/var/b	nd/users/bnd005/M	latrix_tutorial/MATR	RIX_v2.1.0/run/ppz01_	_MATRIX/result/run_Z_ons	shell_LO/LO-run/distribu	tionsLO — ssh bnd0	05@bnd01.iihe.ac.b
Fi:	le Edit Opt	ions Buffers Tools	; Help						
#	left-edge	right-edge	scale-central	central-error	scale-m	in min-error	scale-max	max-error	rel-down
	0	0.4	9568545.5	29160.3	8 8498220	.1 25956.8	10522877.	32059.6	-11.19%
	0.4	0.8	9457907.5	29396.6	8415650	.7 26334.7	10385636.	32118.3	-11.02%
	0.8	1.2	9269091.2	30938.0	8274944	.5 27831.1	10151223.	33680.1	-10.73%
	1.2	1.6	8909453.2	40351.2	7990765	.3 36501.2	9721126.6	43722.1	-10.31%
	1.6	2	8554068.6	37922.6	7716082	.1 34401.6	9290072.7	40996.2	-9.80%
	2	2.4	7999456.6	26386.3	3 7268964	.1 24008.3	8634291.1	28458.0	-9.13%
	2.4	2.8	7186338.0	31852.7	6591525	.4 29136.3	7693900.5	34193.4	-8.28%
	2.8	3.6	4605174.2	10158.4	4305013	.1 9435.54	4847905.5	10757.6	-6.52%
-Ul	U-:F1	y_Z-ATLASL0.dat	All L10 (Fundamental) -					
End	d of buffer								
•	🔒 🦲 📷 mars	— bnd005@bnd01·/var/br	nd/users/bnd005/Ma	trix tutorial/MATRIX	v2.1.0/run/ppz0			$R(Z \rightarrow t')$	$t) \simeq 3.$
						ATLAS d	ata		
F1	le Edit Opt	ions Butters loois	5 Не⊥р	+-+-1					
H [#]	Iert-eage	right-eage exp-c	ross-section	total-error I	umi-error				
	0	0.4	357.152	0.010232	0.52312				
	0.4	0.0	353.152	0.0120//	0.300/4	first hin ()	$< v_{-} < ($		
	0.0 1 0	1.2	343.90J 226 105	0.014000	6 05151			J •] •	
	1.2	1.0	222 / 22	0.031117	5 80/60				
	2.0	2 4	362 073	1 222500	5.00409	$\int \mathbf{O} \cdot \mathbf{\sigma} = \mathbf{O} \cdot \mathbf{I}$	$nn \rightarrow 7 \rightarrow$	$(\mathcal{P}^+ \mathcal{P}^-) =$	321 nh 、
	2 /	2.4	273 108	1 477050	4 01756				
	2.4	2.0	173 171	1 4/88/0	3 11708				
	2.0	0.0	1/0.1/1	1.440040	3.11/00	data o.	$ (nn \rightarrow$	$(\mathcal{P}^+ \mathcal{P}^-) -$	357 nh 🖌
-11	U-:F1	v Z-ATLAS data da	t A11 110	(Eundamental)		Gata. OAT	LASVPP		
- En	d of buffer			(Fundamentedr)					
	a or barrer					(Lastura) hands on sass		Sontombor 6 20	$\mathbf{N} \mathbf{A}$

[[bnd005@bnd01 distributions__LO]\$ ls



task:	Check out the prepared NNLO /var/bnd/theo/matrix/p
	Does the NNLO QCD on-shell
	data? And if not, why can you ima
	Check instead the prepared off-s
	/var/bnd/theo/matrix/p
	Does it compare better or worse
hint:	Compare the input files of the tv

wget https://wwwth.mpp.mpg.de/members/wieseman/download/ lectures and talks/BND Summer School Lecture/matrix files.tar

- run inside
- pz01 MATRIX
- Z rapidity distribution compare well with agine why not?
- shell Z production NNLO run inside
- peex02 MATRIX
- e to data? What is the main difference?
- wo runs to find the difference.

(reminder, the data is here: /var/bnd/theo/matrix/ATLAS DY data)

or download and extract:



task:	Check out the prepared NNLO /var/bnd/theo/matrix/p
	Does the NNLO QCD on-shell
	data? And if not, why can you ima
	Check instead the prepared off-s
	/var/bnd/theo/matrix/p
	Does it compare better or worse
hint:	Compare the input files of the tv

answer:	The on-shell Z (times BR) rap
	data. The NNLO off-shell resu
	The reason is the $80 \leq m_{\ell^+\ell^-}$
	~5% of the cross section. The
	momenta (by construction), m

- run inside
- pz01_MATRIX
- Z rapidity distribution compare well with agine why not?
- shell Z production NNLO run inside
- peex02_MATRIX
- e to data? What is the main difference?
- wo runs to find the difference.
- bidity distribution at NNLO is ~5% above the ult agrees within a few permille with the data. ≤ 100 mass window cut, which removes on-shell process is inclusive over the lepton nissing this effect.







Marius Wiesemann (MPP Munich)





Marius Wiesemann (MPP Munich)













QCD and Monte Carlo event generators (Lecture 2 — hands-on session)

September 6, 2024



- task: Compile diphoton production. Look at the input files of diphoton and Drell-Yan production. Do you notice any important difference?
- hint: It has to do with the photons in the final state for diphoton production.
- tip: Instead of compiling (which may take some time) you can compare the input files directly inside here (process shortcut you need to figure out): run/input_files/\${process}/default.input.MATRIX/



Yan production. Do you notice any important difference?

🦲 😑 💼 mars — bnd005@bnd01:/var/bnd	d/users/	bnd005/	Matrix_tutorial/M
File Edit Options Buffers Too	ols H	elp	
<pre>## Settings for fiducial cuts #</pre>	-\ -/		
<pre># Jet algorithm iet algorithm = 3</pre>	#	(1) 0	ambridge-A
$jet_R_definition = 0$	#	(0) p	seudo-rapi
jet_R = 0.4	#	Delta	R
# Frixione isolation			
frixione_isolation = 1	#	switc	h for Frix
	#	(1) w	ith frixio
	#	(2) w	ith frixio
frixione_n = 1	#	expon	ent of del
frixione_delta_0 = 0.4	#	maxim	al cone si
frixione_epsilon = 0.5	#	photo	n momentum
<pre>#frixione_fixed_ET_max = 5.</pre>	#	fixe	d maximal
-UU-:F1 parameter.dat	49%	L85	(Fundamen

- task: Compile diphoton production. Look at the input files of diphoton and Drell-
- hint: It has to do with the photons in the final state for diphoton production.

ATRIX_v2.1.0/run/input_files/ppaa02/default.input.MATRIX — ssh bnd005@bnd01.iihe.a...

```
achen (2) kT (3) anti-kT
dity (1) rapidity
```

```
ione isolation (0) off;
ne_epsilon, used by ATLAS;
ne_fixed_ET_max, used by CMS
ta-term
ze
fraction
pT inside cone
```

tal)



Yan production. Do you notice any important difference?

answer: Photons in the final state need to be isolated in an infrared-safe way. Frixione's smooth-cone isolation.



 $E_T^{\text{had/part}} \leq E_T^{\max}(\delta) = E_T^{\text{ref}}$

- task: Compile diphoton production. Look at the input files of diphoton and Drell-
- hint: It has to do with the photons in the final state for diphoton production.
 - Otherwise, you need to include non-perturbative fragmentation functions, which most calculations/codes (including MATRIX) do not provide. An infared-safe approach that completely kills the fragmentation component is
 - Isolate photon ("throw away" all hadron/partons) when for given cone (radius δ_0) around photon, for every cone $\delta < \delta_0$ the entire hadronic/partonic transverse energy inside is smaller than a reference energy scale that smoothly decreases with δ .

$$e^{f} \cdot \left(\frac{1 - \cos|\delta|}{1 - \cos\delta_{0}}\right)^{n}, \quad \forall \delta \leq \delta_{0}, \quad E_{T}^{\text{ref}} = \epsilon_{\gamma} p_{T}^{\gamma} \text{ or } E_{T}^{\text{ref}} =$$



- task: Look at prepared NNLO runs in folders for diphoton and Drell-Yan causes this behaviour?
- hint: It has to do with what we just discussed.
- tip:

/var/bnd/theo/matrix/ppz01_MATRIX/run_matrix_tutorial_8TeV_on-shell_Z_ATLAS/result/ Drell-Yan: result..MATRIX.NNLO.result/fixed-scale/complete/band.qTcut.NNLO.QCD NNLORUN.dat

/var/bnd/theo/matrix/ppaa02 MATRIX/run matrix tutoral diphoton/result/ diphoton: result..MATRIX.NNLO.result/dynamic-scale-1/7-point/band.qTcut.NNLO.QCD NNLORUN.dat

production (see below). Look at the dependence of the cross section on the q_T -subtraction cutoff r_{cut} of the two processes. What do you notice? What

Instead of looking at/plotting the whole $r_{\rm cut}$ dependence, look at NNLO cross section in the summary of the two processes. Do you notice a difference in the results between the two processes at a fixed $r_{\rm cut}$ compared to the $r_{\rm cut} \rightarrow 0$ extrapolation? What happens to the numerical/systematical error?



Drell-Yan

#qTcut	central scale	
#	xiR=1 xiF=1	
0	33958573.	14976.349
0.15	33967335.	9840.7316
0.16	33967139.	9637.6593
0.17	33970123.	9357.7266
0.18	33964391.	9277.9947
0.19	33967671.	9656.8093
0.2	33969563.	8968.4672
•••	•••	• • •
0.95	33973627.	8482.9472
0.96	33964844.	5304.3165
0.97	33967026.	5327.2331
0.98	33966695.	5269.2587
0.99	33962589.	5355.0294
1	33964258.	5215.9660
diphoton:	/var/bnd/theo/matrix/p resultMATRIX.NNLO.re	paa02 <u>MATRI</u> sult/dynami

Iders for diphoton and Drell-Yan e dependence of the cross section on the processes.What do you notice? What

issed.

hole r_{cut} dependence, look at NNLO cross processes. Do you notice a difference in sses at a fixed r_{cut} compared to the ens to the numerical/systematical error?

n_matrix_tutorial_8TeV_on-shell_Z_ATLAS/result/ le/complete/band.qTcut.NNLO.QCD__NNLORUN.dat

X/run_matrix_tutoral_diphoton/result/ c-scale-1/7-point/band.qTcut.NNLO.QCD__NNLORUN.dat



Drell-Yan

#qTcut	central scal	.e
#	xiR=1 xiF=1	
0	33958573.	14976.349
0.15	33967335.	9840.7316
0.16	33967139.	9637.6593
0.17	33970123.	9357.7266
0.18 extremely	33964391.	9277.9947
0.19 otoblo	33967671.	9656.8093
0.2 Stable ,	33969563.	8968.4672
wariation	• • •	0.01 % …
0.95	33973627.	8482.9472
0.96 Permille	33964844.	5304.3165
0.97 eve	33967026.	5327.2331
0.98	33966695.	5269.2587
0.99	33962589.	5355.0294
1	33964258.	5215.9660
diphoton: /var/b result	ond/uneo/matrix MATRIX.NNLO.	/ppaa02_MATRI result/dynami

Iders for diphoton and Drell-Yan e dependence of the cross section on the processes.What do you notice? What

issed.

hole r_{cut} dependence, look at NNLO cross processes. Do you notice a difference in sses at a fixed r_{cut} compared to the ens to the numerical/systematical error?

n_matrix_tutorial_8TeV_on-shell_Z_ATLAS/result/ le/complete/band.qTcut.NNLO.QCD__NNLORUN.dat

X/run_matrix_tutoral_diphoton/result/ c-scale-1/7-point/band.qTcut.NNLO.QCD__NNLORUN.dat



Drell-Yan

#qTcut	central scale		#	central scale	9
#	xiR=1 xiF=1		2 #	$mu_R = 1.0$ -	mu_F =
0	33958573.	14976.349	0	37663.925	205.893
0.15	33967335.	9840.7316	0.15	38068.859	31.0946
0.16	33967139.	9637.6593	0.16	38094.585	30.5078
0.17	33970123.	9357.7266	0.17	38120.731	30.2565
0.18 extremely	33964391.	9277.9947	0.18	38152.198	29.8331
0.19	33967671.	9656.8093	0.19	38169.268	29.4598
0.2 Stable,	33969563.	8968.4672	0.2	38198.945	30.0621
variation	• • •	0.01 %…	F	$\bullet \bullet \bullet$	•••
0.95 at sud-	33973627.	8482.9472	0.95	39307.604	24.1801
0.96 Permille	33964844.	5304.3165	0.96	39317.268	24.1681
0.97 eve	33967026.	5327.2331	0.97	39320.553	24.1764
0.98	33966695.	5269.2587	0.98	39334.327	24.1390
0.99	33962589.	5355.0294	10.99	39338.161	24.1260
1	<u>33964258.</u>	5215.9660	1	39347.663	24.1403
diphoton: /var/	bng/matri	x/ppaa02_MATRIX/r	un matrix	_tutoral_diphoton/resul	r/ 24.1403
resul	t. MATRIX.NNLO	.result/dynamic-s	cale-1/7-j	point/band.qTcut.NNLO.Q	CDNNLORUN

Diphoton Production

diphoton



Drell-Yan

#qTcut		central scal	Le	#	central scal	Le
#		xiR=1 xiF=1	1	#	$mu_R = 1.0$	$ mu_F =$
0		33958573.	14976.349	0	37663.925	205.893
0.15		33967335.	9840.7316	0.15	38068.859	31.0946
0.16		33967139.	9637.6593	0.16	38094.585	30.5078
0.17		33970123.	9357.7266	0.17	38120.731	30.2565
0.18	extremely	33964391.	9277.9947	0.18	38152.198	29.8331
0.19		33967671.	9656.8093	0.19 large T _{cut}	38169.268	29.4598
0.2	stable,	33969563.	8968.4672	0.2 dependence	38198.945	30.0621
•••	variation	• • •	0.01 % …	wariation at	•••	3.4 % …
0.95	at Sud-	33973627.	8482.9472	0.95 percent	39307.604	24.1801
0.96	permille	33964844.	5304.3165	0.96	39317.268	24.1681
0.97	level	33967026.	5327.2331	0.97	39320.553	24.1764
0.98		33966695.	5269.2587	0.98	39334.327	24.1390
0.99		33962589.	5355.0294	0.99	39338.161	24.1260
1		33964258.	5215.9660	1	39347.663	24.1403
diphoto	n. /var/b	ng/zneo/matri	x/ppaa02_MATRIX/r	un_matrix_tutoral	_cipnoton/resu	ITT/ 24.1403
dipilott	result	MATRIX.NNLO	.result/dynamic-s	cale-1/7-point/ba	nd.qTcut.NNLO.	QCDNNLORUN

Diphoton Production

diphoton



task:	Look at prepared NNLO runs in
	production (see below). Look at
	q_T -subtraction cutoff r_{cut} of the t
	causes this behaviour?

hint: It has to do with what we just discussed.

answer: Photon isolation causes the power corrections to turn linear instead of the usual quadratic behaviour. This substantially worsens the $r_{\rm cut}$ convergence and induces larger systematic uncertainties (see large num./syst. error of diphoton cross section).



QCD and Monte Carlo event generators (Lecture 2 – hands-on session)

September 6, 2024

Go and run the code on some cluster!

MATRIX v1.0.0/config/Matrix configuration handles configuration, like: mode to choose local/cluster running,

cluster name to choose cluster (LSF, slurm, ...)

```
# MATRIX configuration file #
# This file contains all parameters to configure MATRIX
# In the run_folders this is the link to the central configuration file
# in MATRIX/config/; you can replace the link by a copy to have individual
# configurations for the different processes
# Editor to be used to edit input files from MATRIX shell
# (default: use the one specified under environmental variable EDITOR)
#default_editor = emacs # eg, emacs, vi, nano, ...
# runmode of MATRIX: 0 -- multicore (default)
                    1 -- cluster
mode = 0
###===============####
## cluster parameter ##
###===============####
# Name of cluster currently supported:
   slurm, LSF (eg, lxplus), condor, qsub (Torque/OpenPBS tested+working; PBS, SGE not tested)
cluster_name = LSF
# Queue/Partition of cluster to be used for running
cluster_queue = 2nw
# Maximal runtime for a single process on a single node,
# too low values may lead failure of the code
#cluster_runtime = 2-00:00:00
# add customizable lines at the beginning of cluster submission file
# this allows to add certain cluster-specific requirements as options to the submission
# eg: cluster_submit_line1 = #SBATCH --mem-per-cpu=4000
     to increase the memory of a slurm job on certain clusters
#cluster_submit_line1 =
#cluster_submit_line2 =
#cluster_submit_line3 =
```

(soft link in each \${process id} MATRIX/input/Matrix configuration)





Thank You I



[Alekhin, Kardos, Moch, Trócsányi '21]

ATLAS (7 TeV, 4.6 fb⁻¹)



Marius Wiesemann (MPP Munich)



[Alekhin, Kardos, Moch, Trócsányi '21]



ATLAS (7 TeV, 4.6 fb⁻¹)



$r_{cut} \rightarrow 0$ extrapolation in MATRIX [Grazzini, Kallweit, MW '17]



[Gehrmann, Gehrmann-De Ridder, Glover, Huss et al.]
[Buonocore, Kallweit, Rottolli, MW '21]

$$\Delta\sigma^{\rm linPCs}(r_{\rm cut}) = \int d\Phi_F \int_{\epsilon}^{r_{\rm cut}} dr' \left(\frac{d\sigma^{\rm CT}}{d\Phi_F dr'}\Theta_{\rm cuts}(\Phi_F^{\rm rec}) - \frac{d\sigma^{\rm CT}}{d\Phi_F dr'}\Theta_{\rm cuts}(\Phi_F)\right),$$

based on observation: linPCs described by recoil [Ebert, Michel, Stewart, Tackmann '21]





$$\Delta \sigma^{\rm linPCs}(r_{\rm cut}) = \int d\Phi_F \int_{\epsilon}^{r_{\rm cut}} dr' \left(\frac{d\sigma^{\rm CT}}{d\Phi_F dr'} \Theta_{\rm cuts}(\Phi_F^{\rm rec}) - \frac{d\sigma^{\rm CT}}{d\Phi_F dr'} \Theta_{\rm cuts}(\Phi_F) \right),$$



$$\Delta \sigma^{\rm linPCs}(r_{\rm cut}) = \int d\Phi_F \int_{\epsilon}^{r_{\rm cut}} dr' \left(\frac{d\sigma^{\rm CT}}{d\Phi_F dr'} \Theta_{\rm cuts}(\Phi_F^{\rm rec}) - \frac{d\sigma^{\rm CT}}{d\Phi_F dr'} \Theta_{\rm cuts}(\Phi_F) \right),$$



$$\Delta \sigma^{\rm linPCs}(r_{\rm cut}) = \int d\Phi_F \int_{\epsilon}^{r_{\rm cut}} dr' \left(\frac{d\sigma^{\rm CT}}{d\Phi_F dr'} \Theta_{\rm cuts}(\Phi_F^{\rm rec}) - \frac{d\sigma^{\rm CT}}{d\Phi_F dr'} \Theta_{\rm cuts}(\Phi_F) \right),$$





Marius Wiesemann (MPP Munich)





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[Bierweiler, Kasprzik, Kühn '13]

[Hollik Meier '04], [Accomando, Denner, Meier '06] [Accomando, Denner, Meier '06]



Marius Wiesemann (MPP Munich)

QCD and Monte Carlo event generators (Lecture 2 — hands-on session)

NLO EW

on-shell:

[Bierweiler, Kasprzik, Kühn, Uccirati '12], [Bierweiler, Kasprzik, Kühn '13], [Baglio, Ninh, Weber '13] off-shell:

[Biedermann, Denner, Dittmaier, Hofer, Jäger '16], [Biedermann, Billoni, Denner, Dittmaier, Jäger '16], [Kallweit, Lindert, Pozzorini, Schönherr '17], [Grazzini, Kallweit, Lindert, Pozzorini, Rathlev, MW '19]



September 6, 2024



































Example I: $pp \rightarrow 2\ell 2\nu$ (WW)



Marius Wiesemann (MPP Munich)

QCD and Monte Carlo event generators (Lecture 2 — hands-on session)

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bin



... to actually do anything useful, but just plain running ...











process folder:

• • •

fil

fil

📄 Own_Codes — ssh -A -t mariusw@tell.physik.uzh.ch ssh -Y -A -t d

[[mariusw:/data/mariusw/publish_MATRIX_v2.2/MATRIX/test_code/MATRI ppz01/NNLO.QT-CS/21/CT2.QCD/run.0] ls log/*.in log/bb~_z.in log/dd~_z.in log/uu~_z.in ppz01/NNLO.QT-CS/21/CT2.QCD/run.0] ../ppz01 < log/dd~_z.in</pre>



[**[mariusw:/d**ata/mariusw/publish_MATRIX_v2.2/MATRIX/test_code/MATRI





ppz01/NNLO.QT-CS/21/CT2.QCD/run.0] ls log/*.in log/bb~_z.in log/dd~_z.in log/uu~_z.in ppz01/NNLO.QT-CS/21/CT2.QCD/run.0] ../ppz01 < log/dd~_z.in</pre> BEGIN filmunich::walltime_start: Thu Feb 1 19:35:32 2024



process folder:

- Own_Codes ssh -A -t mariusw@tell.physik.uzh.ch ssh -Y -A -t c
- [mariusw:/data/mariusw/publish_MATRIX_v2.2/MATRIX/test_code/MATRI
- [mariusw:/data/mariusw/publish_MATRIX_v2.2/MATRIX/test_code/MATRI
- event_set::initialization_input: (event_set::output_particle_defi





\${MATRIX_folder}/matrix

imports

global definitions

read command line arguments

read config/MATRIX_configuration & set paths

interactive shell (figure out \${process_id})

license agreement

create input file (for current or all processes)

main compilation

- → install amplitude provider (OpenLoops, Recola, ...)
- → install external libraries (tdhpl, cln, ginac, VVamp, ...)
- create Makefile and compile process
- → download OpenLoops amplitudes

create process folder run/\${process_id}_MATRIX

takes care of the entire compilation & setup of the code to be run

quite compact: just ~ 420 lines

\${MATRIX folder}/matrix



sys.path.append(pjoin(os.path.dirname(os.path.realpath(__file__)),"bin/modules")) from initialize classes matrix import *

\${MATRIX folder}/bin/modules/initialize_classes_matrix.py

\${MATRIX_folder}/bin/modules/handle_*.py

🔍 🗢 🔍 関	MATRIX — -bash — 95×69
[[mars: ~/Uni/Own_Codes/publish_MATRIX_v2.	1.0/MATRIX] ls bin/modules/*py
<pre>bin/modules/combine_distributions.py</pre>	<pre>bin/modules/handle_lhapdf.py</pre>
<pre>bin/modules/combine_results.py</pre>	<pre>bin/modules/handle_log.py</pre>
<pre>bin/modules/custom_WW_gnuplot.py</pre>	bin/modules/handle_output.py
<pre>bin/modules/handle_cluster.py</pre>	bin/modules/handle_process.py
<pre>bin/modules/handle_folder.py</pre>	bin/modules/handle_process_folder.py
<pre>bin/modules/handle_gnuplot.py</pre>	<pre>bin/modules/handle_result.py</pre>
<pre>bin/modules/handle_input.py</pre>	bin/modules/initialize_classes.py
<pre>bin/modules/handle_input_files.py</pre>	bin/modules/initialize_classes_matrix.py
<pre>bin/modules/handle_input_matrix.py</pre>	
[mars:~/Uni/Own_Codes/publish_MATRIX_v2.1.0/MATRIX]	

\${MATRIX folder}/bin/modules/handle_process.py → contains main class for matrix compilation

\${MATRIX folder}/bin/modules/handle input files.py \rightarrow creates input files for each process: (file_)parameter.dat, (file_)model.dat, (file_)distribution.dat inside \$MATRIX_folder/run/run/input_files/\${process_id}





\${MATRIX folder}/matrix

imports

global definitions

define existing processes and their description

process name.process description["pph21"] = "on-shell Higgs production' process name.process description["ppz01"] = "on-shell Z production"

define relevant OpenLoops amplitudes

define amplitudes to be downloaded+compiled from OpenLo openloops amplitudes dict = {} openloops amplitudes dict["pph21"] = ["heftpphj"] openloops_amplitudes_dict["ppz01"] = ["ppvj", "ppvj_ew"]

define order of printout

process name.process order = ["pph21","ppz01","ppw01","ppwx01","ppeex02","ppnenex02" "ppenex02", "ppexne02", "ppaa02", "ppeexa03", "ppnenexa03", "ppenexa03", "ppexnea03", "ppz z02","ppwxw02","ppemexmx04","ppeeexex04","ppeexnmnmx04","ppemxnmnex04","ppeexnenex04 , "ppemexnmx04", "ppeeexnex04", "ppeexmxnm04", "ppeexexne04", "ppttx20", "ppaaa03"]

set requirements (tdhpl,VVamp, ...)

```
tdhpl_processes = ["ppeexa03","ppnenexa03","ppexnea03","ppenexa03","ppttx20", "ppbbx*
20"1
qqVVamp_processes = ["ppemexmx04", "ppeeexex04", "ppeexnmnmx04", "ppemxnmnex04", "ppeexn"
enex04", "ppemexnmx04", "ppeeexnex04", "ppeexmxnm04", "ppeexexne04"]
  until fixed in Makefile WZ needs to compile ggVVamp amplitude
ggVVamp_processes = qqVVamp_processes
process name.available processes=copy.copy(process_name.process_order)
```









\${MATRIX folder}/matrix

imports

global definitions

read command line arguments

read config/MATRIX_configuration & set paths

interactive shell (figure out \${process_id})

license agreement

\${MATRIX folder}/matrix

imports

global definitions

read command line arguments

read config/MATRIX_configuration & set paths

interactive shell (figure out \${process_id})

license agreement

create input file (for current or all processes)

default input: \${MATRIX_folder}/config/process_inputs.py \bullet

```
process_inputs.py
        n21 input...
proc dict["ppz01"]["process class"] = "pp-z+X"
proc dict["ppz01"]["scale ren"] = "91.1876"
 proc_dict["ppz01"]["scale_fact"] = "91.1876"
proc_dict["ppz01"]["dynamic_scale"] = "0"
proc_dict["ppz01"]["factor central scale"] = "1"
scale dict["ppz01"] = ['0: fixed scale above', '1: invariant mass P
Q) of system (of the colourless final states)', '2: transverse mage
ss (mT^2=Q^2+pT^2) of system (of the colourless final states)']
cuts_dict["ppz01"]["block"] = ['jet']
cuts dict["ppz01"]["user"] = []
 #{{{ ppw01 input...
```

- \${MATRIX_folder}/bin/modules/handle_input_files.py Creates (file_)parameter/model/distribution.dat inside \$MATRIX folder/run/run/input files/\${process_id}
- create input files for all processes:
 - ./matrix ppz01 -clean create input_file





\${MATRIX_folder}/matrix

imports

global definitions

read command line arguments

read config/MATRIX_configuration & set paths

interactive shell (figure out \${process_id})

license agreement

create input file (for current or all processes)

main compilation

- → install amplitude provider (OpenLoops, Recola, ...)
- → install external libraries (tdhpl, cln, ginac, VVamp, ...)
- create Makefile and compile process
- download OpenLoops amplitudes

• \${MATRIX folder}/bin/modules/handle process.py

```
handle_process.py
class compile_process():
                           cocess in, matrix dir in, nr cores in)...
   def create makefile(self):
        if self.do resum:
            cloud_makefile = pjoin(self.matrix_dir,"Makefile.clean_res")
        else:
            cloud_makefile = pjoin(self.matrix_dir,"Makefile.clean")
       self.makefile = pjoin(self.matrix_dir, "Makefile")
       shutil.copy(cloud makefile, self.makefile)
        inp.input_change_entry(self.makefile,"MAINPATH", self.matrix_dir)
       inp.input_change_entry(self.makefile,"LHAPDF_CONFIG", self.path_to_lhapdf)
       inp.input_change_entry(self.makefile,"GSL_CONFIG",self.path_to_gsl)
       inp.input_change_entry(self.makefile,"OpenLoops_CONFIG", self.path_to_openloops)
        inp.input_change_entry(self.makefile,"GINAC_DIR",self.ginac_dir)
       inp.input_change_entry(self.makefile,"CLN_DIR", self.cln_dir)
        inp.input_change_entry(self.makefile,"FORTRAN_LIB_PATH", self.libgfortran_dir)
       inp.input_change_entry(self.makefile, "RECOLA_DIR", self.recola_dir)
       inp.input_change_entry(self.makefile, "CHAPLIN DIR", self.chaplin dir)
        if self.do resum:
            inp.input_change_entry(self.makefile, "MOREDIR", self.more_dir)
       inp.input_change_entry(self.makefile,"HOMEPATH", self.matrix dir)
        if self.process == "ppaaa03":
            inp.input_change_entry(self.makefile, "2LOOP_DIR", self.ppaaa03_2loop_dir)
                                nore dir = self.more dir)...
                                     vamp_dir = self.qqvvamp_dir)...
                                    vamp_dif = self.ggvvamp_dif)...
gvvamp_dir = self.ggvvamp_dir)...
                          [(self, ggvvamp_e_
elf,tdhpl_tar)...
self, tdhpl_dir = self.tdhpl_dir)...
                               ampzz dir = self.ampzz dir)...
-:**- handle process.py Top (55,0)
                                          Git-master (Python Fld ElDoc) 11:48am 1.46
```



\${MATRIX_folder}/matrix

imports

global definitions

read command line arguments

read config/MATRIX_configuration & set paths

interactive shell (figure out \${process_id})

license agreement

create input file (for current or all processes)

main compilation

- → install amplitude provider (OpenLoops, Recola, ...)
- → install external libraries (tdhpl, cln, ginac, VVamp, ...)
- create Makefile and compile process
- download OpenLoops amplitudes

create process folder run/\${process_id}_MATRIX

• create process folder

\${MATRIX_folder}/run/\${process_id}_MATRIX
based on predesigned tarballs

\${MATRIX_folder}/run/run.\${process_id}.tar



\${MATRIX_folder}/bin/run_process

imports

global definitions

read command line arguments

```
class: inputs()
```

```
class: run_class()
```

main part I (setup, readin)

- print banner, read config/MATRIX_configuration
- → get name of run & create run-folder/folder structure
- → get run mode & adjust folder structure accordingly
- → read input files & set main C++ inputs
- → set global parameters from read input files (config&run)
- → assign grids for contributions

some wrapper functions for actual run

main part II (actual run)

- \rightarrow grid-run \rightarrow pre-run \rightarrow main-run
- → result combination → citation list into CITATION.bib
- → print result summary on-screen → gnuplot

takes care of the running/computing all relevant cross-section contributions after reading the relevant inputs

quite a mess! ...almost 6000 lines!

\${MATRIX folder}/bin/run process

imports

global definitions

read command line arguments

```
class: inputs()
```

```
class: run_class()
```

main part I (setup, readin)

- print banner, read config/MATRIX_configuration
- → get name of run & create run-folder/folder structure
- → get run mode & adjust folder structure accordingly
- → read input files & set main C++ inputs
- → set global parameters from read input files (config&run)
- → assign grids for contributions

some wrapper functions for actual run

main part II (actual run)

- → grid-run → pre-run → main-run
- → result combination → citation list into CITATION.bib
- → print result summary on-screen → gnuplot

main part of code at the end of the file (last ~800 lines)! part I: setup of folders and readin of inputs part II: actual run of all contribution through all stages



\${MATRIX_folder}/bin/run process

imports	

rt own modules sys.path.append(pjoin(os.path.dirname(os.path.realpath(__file__)),"modules")) from handle cluster import * from handle_lhapdf import lhapdf from handle_output import banner,output_saver from handle folder import which from initialize classes import out, prc, log, run_name, edit_input, fold, res, Tee, cite from handle_gnuplot import gnuplot



\${MATRIX folder}/bin/modules/initialize classes.py





\${MATRIX folder}/bin/run process

imports	



\${MATRIX_folder}/bin/modules/handle_input.py → implementes interactive shell, sets name of run, ...

\${MATRIX_folder}/bin/modules/handle_output.py -> prints banner, handles on-screen output, creates output logfile

\${MATRIX_folder}/bin/modules/handle_folder.py → saves relevant paths, delete/move/clean/tar run folder, ...

\${MATRIX_folder}/bin/modules/handle_cluster.py → implements cluster submission for several clusters

\${MATRIX_folder}/bin/modules/handle_lhapdf.py -> checks if required set is installed, downloads PDF sets, ...

\${MATRIX_folder}/bin/modules/handle_log.py → handles log files during run, creates lock file, ...

\${MATRIX_folder}/bin/modules/handle_result.py \rightarrow creates and fills result folder, includes citations, ...

\${MATRIX folder}/bin/modules/handle gnuplot.py \rightarrow creates gnuplot output and plots results into pdf files


\${MATRIX folder}/bin/run process

imports

global definitions

define allowed processes

proper_process_names = ["pph21","ppz01","ppeexa03","ppaa02","ppaaa03"," "ppeex02","ppnenexa03","ppeeexex04","ppemexmx04","ppemxnmnex04","ppexn sea03", "ppenexa03", "ppnenex02", "ppexne02nockm", "ppenex02nockm", "ppexne0 s2", "ppenex02", "ppemexnmx04", "ppeexmxnm04", "pphh22", "ppeexexne04", "ppeese sexnex04", "ppeexnenex04", "ppeexnmnmx04", "ppzz02", "ppw01nockm", "ppwx01ne sockm", "ppw01", "ppwx01", "ppwxw02", "ppttx20", "ppbbx20", "pphjj41heft"]

• define settings for pre-run (parallelization, number of events)

🖻 a list	[parallelization, eve	ent	s]	
default	_settings = {}			
default	<pre>settings["loop"]</pre>	=	[5 , 50000]	
default	<pre>settings["VT2.QCD"]</pre>	=	[5 , 1000000]	# [50 , 10
default	<pre>settings["RVA.QCD"]</pre>	=	[1,1000000]	# [10 , 1
default	<pre>settings["RRA.QCD"]</pre>	=	[1,200000]	

processes with involved settings = ["ppttx20","ppeeexex04","ppemxnmnex 94", "ppeexa03", "ppnenexa03", "ppemexnmx04", "ppenexa03", "ppexnea03", "ppep
9 ≤mxnmnex04","ppemexmx04","ppeexmxnm04","ppeexexne04","ppeeexnex04","ppe sexnenex04","ppeexnmnmx04","ppzz02","ppwxw02","ppaaa03"] involved settings = copy.copy(default settings) involved settings["VA.QEW"] = [25,50000] involved settings["VT2.QCD"] = [100,100000] involved_settings["RVA.QCD"] = [20,100000]

#process specific settings for ppttx20 pre_run_settings["ppttx20"]["RVA.QCD"] = [20,1000000] pre_run_settings["ppttx20"]["RRA.QCD"] = [5,1000000]











\${MATRIX_folder}/bin/run_process

imports

global definitions

- define allowed input parameters of parameter.dat file
 - I. parameters that are identical as in file_parameter.dat

unique_parameters = ["process_class","E","coll_choice","scale_fact","
scale_ren","jet_algorithm","jet_R_definition","jet_R","photon_recombin
sation","photon_R_definition","photon_R","photon_E_threshold_ratio","fr
sixione_isolation","frixione_n","frixione_epsilon","frixione_delta_0","
frixione_fixed_ET_max","pdf_content_modify","pdf_selection","define_pT
missing"]

2. parameters that have specific order in file_parameter.dat

ordered_parameters = ["LHAPDF_LO", "PDFsubset_LO", "LHAPDF_NLO", "PDFsubse et_NLO", "LHAPDF_NNLO", "PDFsubset_NNLO"] # these keywords are defined, so that one can uniquely connect the pare amaters in MATRIX input with the ordered inputs in MUNICH ord_params_keyword = {"LHAPDF_LO": ["type_perturbative_order", "LO", "LHPDF_NLO";"LHAPDF_NLO": ["type_perturbative_order", "NLO", "LHAPDF_NLO";"]

3. parameters with different name in file_parameter.dat

renamed_parameters = ["factor_central_scale","variation_factor","scale_res","dyname ic_scale_res","factor_scale_res"] renamed_parameter_mappings = {} renamed_parameter_mappings["factor_central_scale"] = "prefactor_CV"

4. parameters relevant for script (not file_parameter.dat)

5. parameters relevant for script (not file_parameter.dat)

special_parameters = ["dynamic_scale","switch_distribution","flavor_sc sheme","scale variation","switch off shell","reduce workload","switch quit





\${MATRIX folder}/bin/run process

imports

global definitions

- define allowed input parameters of parameter.dat file
- 6. process dependent user-defined parameters (cuts)

user parameters["ppeex02"] = ["user switch M leplep","user cut min seplep","user_cut max_M_leplep","user_switch R_leplep","user_cut min_R_s
sleplep","user_switch lepton_cuts","user_cut min_pT_lep_1st","user_cut s ⊆min pT lep 2nd"]

- set parameter that are required to be in parameter.dat file mandatory_parameters = ["E","coll choice","save previous result","save previous log", "NLO subtraction method"]
- set default values for parameter (if missing in parameter.dat)

default parameters = {} default parameters["NLO subtraction method"] = 1 # use CS subtraction default parameters["loop induced"] = 0 # no loop-induced contribution default parameters["max_time_per_job"] = 24 # hours default parameters["LHAPDF LO"] = "NNPDF30 lo as 0118"

mapping from model.dat (SLHA format) to file model.dat

model mappings to MUNICH = multidim dict(2) #[Block][number]=parameter name in MUNICH model_mappings_to_MUNICH["MASS"][1]="M_d" model mappings to MUNICH["MASS"][2]="M u" model_mappings_to_MUNICH["MASS"][3]="M_s"













\${MATRIX folder}/bin/run process

imports

global definitions

read command line arguments

class: inputs()

class: run_class()

• core classes of entire MATRIX script

```
class: inputs()
```

class inputs():

"""Class to readin user inputs, wrap them and adjust MUNICH inputs"""

- → handles all input settings, checks inputs
- wraps input from parameter/model/distribution.dat to file_parameter/model/distribution.dat
- → reads config/MATRIX configuration
- \rightarrow creates all input files for runtime extrapolation and result combination

class: run class()

class run class(): """Class to run C++ executable of MUNICH in different modes

- → handles all running from grid-run over pre-run to main-run
- \rightarrow handles runtime extrapolation and result combination
- \rightarrow selects all relevant contributions and subprocesses to be run
- \rightarrow does cluster submission or multicore mode
- \rightarrow determines if run is correctly finished and prints alle on-screen output during running









\${MATRIX_folder}/bin/run_process

imports

global definitions

read command line arguments

```
class: inputs()
```

```
class: run_class()
```

main part I (setup, readin)

through interactive interface/ command-line

```
    print banner, read config/MATRIX_configuration
    get name of run
    get run mode
    & adjust folder structure accordingly
```

- → read input files & set main C++ inputs
- → set global parameters from read input files (config&run)
- → assign grids for contributions

```
run_process — (70 x 46)
       part of the MATRIX execution
  orint("")
 panner = banner("|","|",67,11)
 banner.print matrix()
 print("")
 if args.tar_run: args.run_mode = "tar_run"
 if args.setup_run: args.run_mode = "setup_run"
if args.delete_run: args.run_mode = "delete_run"
 continue_run = args.continue_run
 if continue run:
    out.print_warning("You are trying to continue a run; MAKE SURE THE?
  INPUTS ARE CONSISTENT !!!")
       ead MATRIX configuration file
 config list={}
 inp.input_read_parameter_dat(pjoin("input", "MATRIX_configuration"),con
≤fig list)
 edit input.editor = config_list.get("default_editor","")
       reate new run folder, or overwrite the old if already exists...
all command line to choose inputs or start run in chosen run_mo
   if run should be removed, delete the input/logs/results and stop the
 if run mode == "delete run":
    fold.remove_run()
     exit(0)
   if run should be tarred, tar also the input/log/result folder and st
 elif run mode == "tar run":
     if os.path.exists(fold.run folder path):
        fold.tar_run()
        exit(0)
     else:
        out.print error("Cannot create .tar archive of run folder %s, P
sthat does not exist. Exiting..." % fold.run_folder_path)
                       88% (4903,0) Git:master (Python Fld ElDoc) 12:45
 -:--- run process
```

\${MATRIX_folder}/bin/run_process

imports

global definitions

read command line arguments

```
class: inputs()
```

```
class: run_class()
```

main part I (setup, readin)

- print banner, read config/MATRIX_configuration
- → get name of run & create run-folder/folder structure
- → get run mode & adjust folder structure accordingly
- → read input files & set main C++ inputs
- → set global parameters from read input files (config&run)
- → assign grids for contributions

some wrapper functions for actual run

```
main part II (actual run)
```

- \rightarrow grid-run \rightarrow pre-run \rightarrow main-run
- → result combination → citation list into CITATION.bib
- → print result summary on-screen → gnuplot

```
• • •
                                                run_process
    #####################################
   if not run_mode in ["run_results","run_gnuplot"]:
     if runmode == "cluster":
           cluster = get_cluster_class_from_name[cluster_name](config_list,verbose)
 run = run_class(runmode,grid_folder,main_run_folder,NLO_subtraction,order,set_pa
srallel_runs,grid_assignment,include_loop_induced,config_list)
 if run_mode in ["run", "run_grid_and_pre", "run_grid", "run_without_pre"]:
     run.clear_warmup() # clear previous runs in grid dirs
     run.warmup(1) # run w
     print_restarted_runs() # if there are any, print out restarted runs
if run.errors_flag: out.print_warning("Exception error in python jobs while ?
srunning warmup.")
      rerun_warmup(max_restarts) # if there are jobs that failed
     check warmup() #
      log.move_to_folder(pjoin(fold.log_folder_path,"grid_run")) # move all log fip
  f run_mode in ["run", "run_grid_and_pre", "run_pre", "run_pre_and_main"]:
     check_grid_log() # check logs if grid_run has been done
log.clear_list("restarted_list.log") # remover list with
     if run_mode in ["run_pre", "run_pre_and_main"]: run.clear_pre_run() # clear p?
     run.main_run(-1) # start pre run
     print_restarted_runs() # if there are any, print out restarted runs
if run.errors_flag: out.print_warning("Exception error while doing extrapola
stion runs.")
     rerun_pre_run(max_restarts) # if there are jobs that failed
check_pre_run() # if there are failed pre runs, print error and stop code
log.move_to_folder(pjoin(fold.log_folder_path,"pre_run")) # move all log fil<sup>2</sup>
      run.extrapolate runtimes() # extrapolation of runtimes from pre run result
      try:
          run.print pre run()
      except:
           pass
     run.read_runtimes() # read in output of extrapolation run
check_parallel() # check wether the parallelization is not too high
 if run_mode in ["run_without_pre", "run_main_without_pre"]:
 -:**- run process
                            99% (5692,30) Git:master (Python Fld ElDoc) 12:59am 2.17
```



\${MATRIX_folder}/bin/run_process

imports

global definitions

read command line arguments

```
class: inputs()
```

```
class: run_class()
```

main part I (setup, readin)

- print banner, read config/MATRIX_configuration
- → get name of run & create run-folder/folder structure
- → get run mode & adjust folder structure accordingly
- → read input files & set main C++ inputs
- → set global parameters from read input files (config&run)
- → assign grids for contributions

some wrapper functions for actual run

```
main part II (actual run)
```

- \rightarrow grid-run \rightarrow pre-run \rightarrow main-run
- → result combination → citation list into CITATION.bib
- → print result summary on-screen → gnuplot

```
• • •
                                                 run_process
if run mode in ["run","run main","run pre and main","run without pre","run main P
without pre"]:
         oss section run (main run)
    if run mode == "run main":
          run.read runtimes() # read in output
    check_parallel() # read in output of extrapolation fun
check_parallel() # check wether the parallelization is not too high
run.clear_main_run() # clear main run folders of previous runs
log.clear_list("restarted_list.log") # remove previous restarted job list
    run.main_run(1) # start main run
    print_restarted_runs() # if there are any, print out the restarted runs
if run.errors_flag: out.print_warning("Exception error while running main pre
    rerun_main_run(max_restarts) # if there are jobs that failed
check_main_run() # if there are still failed main runs, print error and stop
log.move_to_folder(pjoin(fold.log_folder_path,"main_run")) # move all log fip
If run_mode in ["run","run_pre_and_main","run_main","run_results","run_without p
 e", "run main without pre"]:
    run.clear results() # remove previous results (if there are any)
    citation_list_run = cite.get_citation_list_run(order,NLO_subtraction)
    citation list process = cite.get citation list process (parameter list)
    citation_list_amplitudes = cite.get_citation_list_amplitudes(parameter_list)
    citation_list_standard = cite.get_citation_list_standard(parameter_list)
    cite.write_citations(pjoin(fold.result_folder_path,"CITATIONS.bib"),parameter
r_list,citation_list_run,citation_list_process,citation_list_standard=citation_l
ist_standard,citation_list_amplitudes=citation_list_amplitudes)# write citations?
    run.combine_results() # combine results and distributions and copy them
    out distributions = ""
    if int(parameter list["switch distribution"]) == 1:
          out_distributions = " (including the distributions)" # if distribut
          run gnuplot() #
    run.print_results_onscreen_and_to_summary_file() # write results
out.print_result("All results%s can be found in:" % out_distributions)
    out.print result(fold.result_folder_path)
elif run_mode == "run_gnuplot":
     trv:
         os.makedirs(pjoin(fold.result_folder_path,"gnuplot"))
     except:
          shutil.rmtree(pjoin(fold.result_folder_path, "gnuplot"))
          os.makedirs(pjoin(fold.result_folder_path,"gnuplot"))
     run gnuplot() #
                                               Git:master (Python Fld ElDoc) 1:02am 1.64
                             Top (1,94)
-:**-
        run process
```

\${MATRIX_folder}/bin/run_process

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                                               Git:master (Python Fld ElDoc) 1:02am 1.64
                             Top (1,94)
-:**-
        run process
```

How to add a user-defined cut

! check out appendix of Matrix Manual !

• add user parameters (user_switch, user_cut) to parameter.dat file of process:

user_switch dy_lep1lep2 = 1 # switch to turn on (1) and off (0) cuts on absolute dy of leptons

user_cut min_dy_lep1lep2 = 0.5 # requirement on absolute rapidity difference of leptons (lower cut)



How to add a user-defined cut

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// get settings for cut on absolute rapidity difference of leptons static int switch_dy_lep1lep2 = USERSWITCH("dy_lep1lep2 "); static double cut_min_dy_lep1lep2 = USERCUT("min_dy_lep1lep2");

// perform cut on absolute rapidity difference of leptons according to settings if (switch_dy_lep1lep2 == 1){ double y_lep1 = PARTICLE("lep")[0].rapidity; double y_lep2 = PARTICLE("lep")[1].rapidity; double dy_lep1lep2 = y_lep1 - y_lep2; if (abs(dy_lep1lep2) < cut_min_dy_lep1lep2) {</pre> osi_cut_ps[i_a] = -1; // cut phase-space point return;

• add cut inside C++ code under path \${MATRIX folder}/prc/ppeex02/user/specify cuts.cxx:



How to add a distribution

! check out appendix of Matrix Manual !

• put distribution into distribution.dat file of a process (check out syntax at end of the file):

```
default.input.MATRIX — less distribution.dat — 109×43
 # MATRIX distribution definition #
# In this file you can customize the distributions created during the run (examples below)
 please read the INSTRUCTIONS at the END OF THIS FILE...
# Info
 Total rates and jet multiplicities (possibly within cuts) will automatically be included
 Add/remove arbitrary distribution-blocks, but always add/remove a full block.
# define distributions
# transverse momentum of the WZ (3-lepton+neutrino) system regularly binned from 0-500 GeV in 10 GeV bins
distributionname = pT_WZ
distributiontype = pT
particle 1
                = lep 1
particle 1
                = lep 2
particle 1
                = lep 3
                = nua 1
particle 1
                = 0.
startpoint
                = 500.
endpoint
binwidth
                = 10.0
```

pre-defined рТ m dm # absdm # mmin # mmax # absy # dy # absdy # dabsy # absdabsy # eta # abseta # deta # absdeta # dabseta # absdabseta # phi # # dR # dReta # ET # mT

How to add a user-defined distribution

! check out appendix of Matrix Manual !

• put distribution into distribution.dat file of a process (check out syntax at end of the file):

distributionname	=	<pre>y_lep1_plus_y_lep2</pre>
distributiontype	=	<pre>sum_of_y</pre>
particle 1	=	lep 1
particle 2	=	lep 2
startpoint	=	0.
endpoint	=	10.
binwidth	=	0.2

• • •

• • •

• if required distribution does not exist implement new distribution inside C++ code under path \${MATRIX folder}/src/observable/xdistribution.cpp:

```
else if (xdistribution_type == "sum_of_y}") {
  double sum_y = 0;
  for (int group = 0; group < particles.size(); group++) {</pre>
    fourvector fourvector_of_current_reconstructed_particle = reconstructedParticles[group]
    sum_y = sum_y + fourvector_of_current_reconstructed_particle.y();
  observable = sum_y;
}
```



•

 \rightarrow select correct name of cluster (from list of preimplemented clusters)

modules — less ../../config/MATRIX_configuration — 109×43 ###=================#### ## cluster parameter ## ###================#### # Name of cluster currently supported: slurm, LSF (eg, lxplus), HTcondor, condor_lxplus (special version working on lxplus HTCondor), condor, PBS, Torque, SGE (PSB and Torque/OpenPBS are identical at the moment) cluster_name = slurm

 \rightarrow select correct name of cluster (from list of preimplemented clusters)

Queue/Partition of cluster to be used for running #cluster_queue = 2nw

Use local scratch directory to run on cluster (speedup for slow shared file systems): # 0 -- standard run on shared file system (default) # 1 -- run in local scratch of nodes; PROVIDE cluster_local_scratch_path BELOW! # NOT IMPLEMENTED YET: 2 -- run without shared file system; PROVIDE cluster_local_scratch_path BELOW! $cluster_local run = 0$

Provide a path to the local scratch directories of the nodes #cluster_local_scratch_path = /PATH/TO/SCRATCH/

small adjustments to the cluster setup can be done via the config/MATRIX configuration file

 \rightarrow NEW: run can be done directly on the local scratch of cluster nodes (substantially reduces load)

• small adjustments to the cluster setup can be done via the config/MATRIX configuration file → add a line specific to your cluster/needs/setup to the cluster submit file

```
# add customizable lines at the beginning of cluster submission file
# this allows to add certain cluster-specific requirements as options to the submission
 eg: cluster_submit_line1 = "#SBATCH --mem-per-cpu=4000"
      to increase the memory of a slurm job on certain clusters
 or you can add commands to the bash commands to source or export stuff on the nodes:
 eg: cluster_submit_line2 = "source /PATH/"
 or: cluster_submit_line3 = "export YOUR_FAVOURITE_VARIABLE=/PATH/"
 You can add as many lines as you want of the structure "cluster_submit_lineX", where X
# is a number which defines the order of the lines added to the submission file.
# If you want/need to use "#", "%" or "=" signs you need to put quotes around the line: "#blah" !
#cluster_submit_line1 = "line 1 added to submission file"
#cluster_submit_line2 = "line 2"
#cluster_submit_line3 = "line 3"
         • • •
# If you need to use quotes in your command you can use:
#cluster_submit_line1 = """variable = "this_has_to_be_in_quotes""""
#cluster_submit_line1 = """variable = "this_has_to_be_in_quotes""""
 If you need to use quotes in your command you can use:
```

- small adjustments to the cluster setup can be done via the config/MATRIX_configuration file

• any major change to the cluster setup has to be done directly inside bin/module/handle_cluster.py



- small adjustments to the cluster setup can be done via the config/MATRIX configuration file
- any major change to the cluster setup has to be done directly inside bin/module/handle cluster.py

there is a class cluster basic() and one class for each implemented cluster

#{{{ imports... #{{{ def: make executable... class: cluster basic(object)... class: slurm cluster(cluster basic)... class: condor cluster(cluster basic)... class: condor lxplus cluster(cluster basic)... class: HTcondor cluster(cluster basic)... class: lsf cluster(cluster basic)... class: pbs cluster(cluster basic)... #{{{ class: sge cluster(cluster basic)... ': pbs_cluster, 'SGE': sge_cluster} ': pbs cluster, 'SGE': sge cluster}

handle_cluster.py

get cluster class from name = {'condor': condor cluster,'HTcondor': HTcondor cluster,'condor lxplu s': condor lxplus cluster, 'LSF': lsf cluster, 'slurm': slurm cluster, 'PBS': pbs cluster, 'Torque





- •

-> class cluster basic() includes all routines (dummy & shared) required to submit runs on cluster

	• • •	ha
	<pre>#{{{ class: cluster_basic(object)</pre>	
	class cluster_basic(object): # basic class t	hat
	<pre>cluster_name = "basic cluster class"</pre>	
	#{{{ def:init(self)	
	<pre># cluster dependend functions:</pre>	
	<pre>#{{{ def: get_list_queue_command_with_multip</pre>	le_
	<pre>#{{{ def: create_batch_file(self,job_name,bat</pre>	tcł
S	rocess_out_path,subprocess_err_path)	
	<pre>#{{{ def: submit_to_cluster(self,batch_file_</pre>	nar
	<pre>#{{{ def: get_job_id_from_content_of_submit_</pre>	out
	# functions that are needed only for certain	c]
	<pre>#{{{ def: create_cd_script(self)</pre>	
	<pre>#{{{ def: create local run script(self)</pre>	
	<pre>#{{{ def: get list command for single job id</pre>	(se
	<pre>#{{{ def: modify_request_by_grepping_job_ids</pre>	(se
	<pre>#{{{ det: modity_request_by_grepping_]ob_ids</pre>	(36

small adjustments to the cluster setup can be done via the config/MATRIX configuration file

• any major change to the cluster setup has to be done directly inside bin/module/handle cluster.py

```
ndle_cluster.py
 handles all cluster types
ids(self,job ids)...
 file name, run path, process, subprocess in path, subprocess
    (self, content)...
usters:
lf, job id)...
elf, request, job_ids)...
```





- small adjustments to the cluster setup can be done via the config/MATRIX configuration file

-> class \${name} cluster() inherits from cluster basic() and overwrites cluster-specific functions

```
• • •
                                             handle_cluster.py
class slurm cluster(cluster basic): # class for slurm cluster inherited from basic cluster class
    cluster name = "slurm"
  [{{ def: init (self,config list,verbose)
    def init (self, config list, verbose):
        cluster basic. init (self, config list, verbose)
        self.command kill job = "scancel"
        try:
             self.command_list_queue = ["squeue", "-p", "%s" % self.config_list["cluster_queue"]]
        except:
             self.command list queue = ["squeue"]
        current user = getpass.getuser()
        self.command list queue current user = ["squeue", "-u", current user]
         self.command_list_queue_with_jobid = ["squeue", "-j"]
        self.job status list = [" PD "," R "," *not set* "," *not set* "]
     def: get list queue command with multiple ids(self, job ids)...
  {{{ def: create batch file(self, job name, batch file name, run path, process, subprocess in path, subprocess
rocess out path, subprocess err path) ...
     def: submit to cluster(self, batch file name)...
    { def: get job id from content of submit output(self, content)...
```

• any major change to the cluster setup has to be done directly inside bin/module/handle_cluster.py

